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Organochlorine Residues in Eggs of Alaskan Seabirds

by

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Abstract

One egg from each of 440 clutches of eggs of 19 species of Alaskan seabirds collected in 1973–76 was analyzed for organochlorine residues. All eggs contained DDE; 98.9% contained PCB's; 84.3%, oxychlordane; and 82.7%, HCB. Endrin was found in only one egg, but DDD, DDT, dieldrin, heptachlor epoxide, mirex, *cis*-chlordane (or *trans*-nonachlor), *cis*-nonachlor, and toxaphene each occurred in at least 22% of the samples.

Concentrations of organochlorines in the samples were generally low. Mean concentrations of eight compounds were highest in eggs of glaucous-winged gulls (*Larus glaucescens*) from three sites: DDE (5.16 ppm, wet weight), dieldrin (0.214 ppm), oxychlordane (0.251 ppm), and PCB's (3.55 ppm) in eggs from Bogoslof Island; heptachlor epoxide (0.037 ppm), *cis*-chlordane (0.075 ppm), and HCB (0.188 ppm) in eggs from Buldir Island; and *cis*-nonachlor (0.026 ppm) in eggs from the Semidi Islands. Highest concentrations of DDD (0.157 ppm), DDT (0.140 ppm), and toxaphene (0.101 ppm) were in eggs of fork-tailed storm-petrel (*Oceanodroma furcata*) from Buldir Island, and the highest concentration of mirex (0.044 ppm) was in fork-tailed storm-petrel eggs from the Barren Islands.

Both frequency of occurrence and concentration of residues in the eggs differed geographically and by species, apparently reflecting non-uniform distribution of organochlorines in the environment, dissimilar feeding habits and migration patterns of the species, or metabolic differences among the species.

The overall frequency of residue occurrence was highest in eggs from the Pribilof Islands, but only three species were represented in the samples collected there. Detectable residues also were more frequent in eggs from the Gulf of Alaska colonies than elsewhere, and the lowest frequency was in eggs from nesting colonies on or near the Seward Peninsula. Regionally, concentrations of DDE and PCB's were usually higher than average in eggs from the Gulf of Alaska and lower than average in eggs from the Aleutian Islands and Bristol Bay. However, within some species there were exceptions to this general pattern, and mean concentrations of most chemicals differed from one site to another within the same region.

Among eggs of species collected in two or more regions, residue frequencies were highest in those of the fork-tailed storm-petrel, tufted puffin (*Lunda cirrhata*), horned puffin (*Fratercula corniculata*), pelagic cormorant (*Phalacrocorax pelagicus*), and northern fulmar (*Fulmarus glacialis*), and lowest in those of common murre (*Uria aalge*), black-legged kittiwake (*Rissa tridactyla*), double-crested cormorant (*Phalacrocorax auritus*), and thick-billed murre (*Uria lomvia*).

On a regional basis, mean concentrations of DDE and PCB's varied significantly among species, but there were few consistent patterns of species differences, except that levels of DDE were always lowest in black-legged kittiwakes and concentrations of PCB's were usually lowest in murres. Also, concentrations of both chemicals (except PCB's in the Gulf of Alaska) were usually higher in northern fulmars than in other species, and the highest concentrations of both DDE and PCB's found in this study were in glaucous-winged gulls in the Aleutian Islands.

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Organochlorine residue data are available from various coastal regions, particularly of the United States and Europe (Ohlendorf et al. 1978*b*). However, there have been relatively few studies of chlorinated hydrocarbon contamination of marine birds in Alaska and other areas of the northern North Pacific.

From 1973 through 1976 we collected eggs of seabirds nesting in Alaska to measure environmental contaminants and to determine differences in residue concentrations among eggs from different nesting sites and from different species. Emphasis was directed at collecting eggs of northern fulmars (*Fulmarus glacialis*), fork-tailed storm-petrels (*Oceanodroma furcata*), pelagic cormorants (*Phalacrocorax pelagicus*), glaucous-winged gulls (*Larus glaucescens*), black-legged kittiwakes (*Rissa tridactyla*), common murres (*Uria aalge*), and tufted puffins (*Lunda cirrhata*) because of differences in both their food habits and ranges, and because of logistical considerations. Eggs of other marine birds were collected opportunistically. We report here the findings of the analyses of these eggs and interpret their significance.

It is unlikely that any seabirds remain uncontaminated by the synthetic organochlorine compounds that have become ubiquitous pollutants (see Ohlendorf et al. 1978*b* for review). The most abundant (and universal) of these compounds is frequently *p,p'*-DDE, a metabolite of *p,p'*-DDT, which is the principal component of the commercial insecticidal mixture. Polychlorinated biphenyls (PCB's), or chlorobiphenyls, are occasionally found in seabirds at concentrations that may induce adverse effects. Other synthetic organochlorine compounds have been detected in seabirds, but almost always at levels substantially lower than those of the DDT and PCB compounds.

Some researchers (see Vermeer and Reynolds 1970; Prestt 1971; Dunnet 1977; Vermeer and Peakall 1977; Ohlendorf et al. 1978*b*; and Ohlendorf 1982) have suggested that birds may serve as useful indicators of marine pollution on a global scale for several reasons: (1) They occur in most estuarine and marine ecosystems, are often numerous, and feed on a wide range of marine organisms. (2) Most species nest colonially and lay large distinctively marked eggs that can be readily analyzed. (3) Certain species are sufficiently conspicuous to enable measurement in changes in numbers and determine population changes; populations with strong traditions for using particular areas for breeding, migration, and wintering permit valid temporal and regional comparisons. (4) Many species are widely distributed and may consequently indicate local environmental changes in many areas throughout their ranges. (5) Because certain seabirds are at the top of food webs (terminal consumers), they accumulate an array of environmental pollutants. (6) Certain birds are physiologically susceptible to particular chemicals, and the observable responses to contaminants (e.g., changes in numbers, reproductive success, behavior, and colony attendance) are often more conspicuous than in other indicator organisms.

Eggs serve as particularly useful sample units for analysis of organochlorines and certain heavy metals—especially mercury—because they constitute distinct units for comparison, do not decompose rapidly, and are easily collected and handled. Some seabird species lay an additional clutch if the first is removed; eggs from those species may thus be taken without adversely affecting populations. This characteristic is of particular importance because studies are sometimes not begun until it is apparent that a population is declining (Vermeer and Reynolds 1970; Prestt 1971).

Organochlorine concentrations in the egg serve as an index to whole-body concentrations found in the female at the time the egg was laid or those in her diet (Cummings et al. 1966; Vermeer and Reynolds 1970; Haegele and Hudson 1974; Driver et al. 1976; Longcore and Stendell 1977; Kan and Jonker-den Rooyen 1978; Custer and Heinz 1980; Haseltine et al. 1980). Although some microbes have the ability to metabolize organochlorine pesticides under certain conditions (Matsumura 1974), putrifaction does not significantly affect residue analysis for DDT and its metabolites (Mulhern and Reichel 1970). During incubation, however, the developing embryo appears to metabolize DDT to DDD and DDE (Abou-Donia and Menzel 1968; Blus et al. 1974). Chemical residue concentrations can be adjusted for the loss of moisture and lipids that occurs during incubation (Stickel et al. 1973). For various reasons, organochlorine residue concentrations in whole egg contents (combined yolk, albumen, and developing embryo) are best expressed on a fresh wet-weight basis; they should be expressed on lipid-weight basis only if the degree of incubation is known and stated (Stickel et al. 1973; Peakall and Gilman 1979).

Methods

Eggs were collected at 18 sites in Alaska, divided among five regions (Table 1, Fig. 1), in 1973–76. Because fiscal limitations precluded a systematic collection of eggs, the collections were made by persons visiting the areas or conducting investigations there for other purposes (collectors are listed in Appendix I).

Entire clutches were collected; eggs were individually wrapped in aluminum foil and placed in plastic containers to retard moisture loss. They were shipped to the Patuxent Wildlife Research Center and refrigerated until they could be processed. Contents were then removed, placed into chemically cleaned jars, and frozen pending analysis. Only one egg per clutch was analyzed.

Egg volumes were measured to the nearest 1.0 mL by water displacement before the contents were removed. Residue concentrations were adjusted to fresh wet weight, assuming a specific gravity of 1.0 as suggested by Stickel et al. (1973).

Preparation of the egg samples and the subsequent solvent extraction, lipid removal, and separation of pesticides

Table 1. *Numbers of samples (clutches) of eggs of Alaskan seabirds collected at different sites in 1973–76. (See Figure 1 for locations of sites.)*

Region and collection site (specific locations included)	Species[a]																			
	CL	NF	F-tSP	LSP	D-cC	PC	R-fC	ACG	G-wG	MG	B-lK	ArT	AlT	CM	T-bM	PG	AM	HP	TP	Total
Gulf of Alaska																				
Copper River Delta (Copper Sands, Egg Island, Strawberry Reef)									36											36
Hinchinbrook Island (Porpoise Rocks)									10		10								10	30
Middleton Island						11			10		10			10						41
Barren Islands			4						2									2	8	16
Amalik Bay									5											5
Kodiak Island (Cathedral Island, Chiniak Bay)	1								17	5	11	3							10	47
Ugaiushak Island					4		1		13					7	6	4		2	22	59
Semidi Islands (Chowiet Island, Kateekuk Island)		16							10										7	33
Shumagin Islands (Hall Island)									10										6	16
Aleutian Islands																				
Bogoslof Island									3					7						10
Buldir Island			7	11		2		1	4		3			1	8		5	1	2	45
Attu Island (Massacre Bay)													6							6
Bristol Bay																				
Round Island											6			4						10
Shaiak Island					3				3		3			5					6	20
Pribilof Islands																				
St. George Island		6												11						17
St. Paul Island											10			10						20
Seward Peninsula																				
Bluff Seabird Cliffs											9			10						19
King Island															10					10
Totals	1	22	11	11	7	13	1	1	123	5	62	3	6	65	24	4	5	5	71	440

[a] CL = common loon, *Gavia immer*; NF = northern fulmar, *Fulmarus glacialis*; F-tSP = fork-tailed storm petrel, *Oceanodroma furcata*; LSP = Leach's storm petrel, *O. leucorhoa*; D-cC = double-crested cormorant, *Phalacrocorax auritus*; PC = pelagic cormorant, *P. pelagicus*; R-fC = red-faced cormorant, *P. urile*; ACG = Aleutian Canada goose, *Branta canadensis leucopareia*; G-wG = glaucous-winged gull, *Larus glaucescens*; MG = mew gull, *L. canus*; B-lK = black-legged kittiwake, *Rissa tridactyla*; ArT = arctic tern, *Sterna paradisaea*; AlT = Aleutian tern, *S. aleutica*; CM = common murre, *Uria aalge*; T-bM = thick-billed murre, *U. lomvia*; PG = pigeon guillemot, *Cepphus columba*; AM = ancient murrelet, *Synthliboramphus antiquus*; HP = horned puffin, *Fratercula corniculata*; TP = tufted puffin, *Lunda cirrhata*.

and PCB's were similar to the procedures used for the analysis of carcasses of bald eagles (*Haliaeetus leucocephalus*) (Cromartie et al. 1975), except that glass thimbles were used. Also, special precautions were taken in rinsing the glassware because we wanted a high level of sensitivity. For eggs collected in 1973 and 1974, and most of those collected in 1975, the procedure for separation of pesticides from PCB's was identical to that described by Cromartie et al. (1975). The samples were analyzed with a gas-liquid chromatograph equipped with an electron-capture detector, automatic sampler, digital processor, and 4% SE-30/6% QF-1 column at 190°C.

For the rest of the eggs collected in 1975 and all of those collected in 1976, the organochlorines were separated into four fractions (rather than three) to insure the isolation of dieldrin and endrin into one individual fraction. These four fractions were analyzed as described above except that a 1.5% OV-17/1.95% QF-1 column was used because it separated *cis*-chlordane from *trans*-nonachlor. (This method was adopted as our laboratory's standard practice before the more recent Alaskan samples had been analyzed.) However, to make the more recent data comparable with those for 1973–75, the values for *cis*-chlordane and *trans*-nonachlor were combined. The amount of *trans*-nonachlor was usually greater than the *cis*-chlordane in the samples where these compounds were measured separately.

Most pesticides (excluding toxaphene) and the PCB's in all the samples were quantitated as described by Cromartie et al. (1975). The procedure for quantitation of toxaphene in the 1974–76 eggs was the same as described by Prouty et al. (1977).

Residues in 10% of the samples were confirmed with an LKB 9000 or Finnigan 4000 series gas chromatograph-mass spectrometer. Operating conditions for the LKB were listed by Cromartie et al. (1975). For the Finnigan they were as follows: flow rate, 30 mL/min helium; a 1.5% OV-17/1.95% QF-1 column temperature-programmed at 2°C per min from 140°C to 225°C; separator, 235°C; and ion source, 300°C.

Samples were analyzed for 13 organochlorines: *p,p'*-DDE, *p,p'*-DDD, *p,p'*-DDT, dieldrin, heptachlor epoxide, mirex, oxychlordane, *cis*-chlordane (or *trans*-nonachlor), *cis*-nonachlor, HCB, toxaphene, endrin, and PCB's. (Chemical names for these compounds are given in Appendix II.)

Average recoveries of pesticides and PCB's from spiked domestic chicken eggs ranged from 83 to 104%. Residue

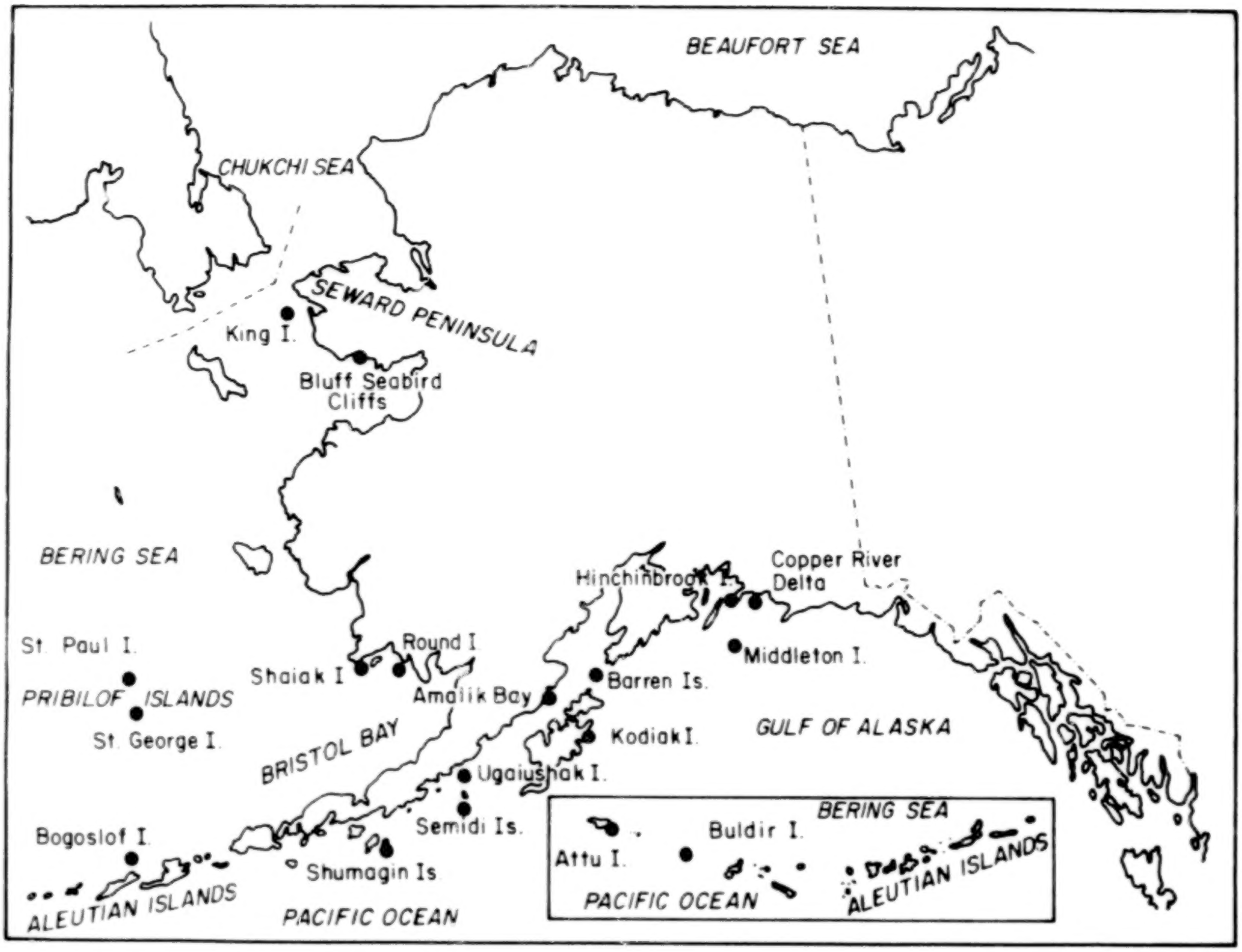

Fig. 1. Collection sites (indicated by closed circles) for eggs of Alaskan seabirds, 1973–76. The sites were located in five regions (all capital letters): Gulf of Alaska, Aleutian Islands, Bristol Bay, Pribilof Islands, and Seward Peninsula. Species and sample sizes for each site are listed in Table 1.

concentrations given in this report were not adjusted on the basis of these recoveries. The lower limit of detection was 0.005 ppm for pesticides other than toxaphene, and 0.02 ppm for toxaphene and PCB's.

A "frequency index" was computed by dividing "total occurrences" by the number of "possible occurrences" to reflect the frequency of organochlorine residue occurrences. Total occurrences are the number of times any of the 13 organochlorines were detected in eggs from that region (or site); possible occurrences are the number of clutches from that region (or site) × 13 chemicals.

Mean organochlorine concentrations in the samples were computed from individual sample values (the residue concentration + 1) that had been transformed to common logarithms. The addition of 1 facilitated the transformation of zero values to logs. After computing mean log values, we subtracted 1 from the value of their antilogs. This returned our measurements to the original units; however, means are geometric rather than arithmetic.

At most sites, eggs were collected in only 1 year. However, in five instances (glaucous-winged gull and tufted puffin at Kodiak Island in 1975 and 1976, and at Ugaiushak Island in 1974 and 1976; thick-billed murre at Ugaiushak Island in 1974 and 1976) we collected eggs of the same species in 2 years at the same sites. We compared means for the separate years and combined them when they were not significantly different. When there were significant differences, data are presented separately for the 2 years.

The data were analyzed by using packaged subroutines from the Statistical Analysis System (Barr et al. 1976). In some instances the presence of many zero values prevented transformation to the normal distribution, but we also calculated means of these log-transformed data (see Ohlendorf et al. 1978*a* for further explanation). We performed a one-way analysis of variance on the log-transformed data for each chemical and used Duncan's multiple range test to detect significant differences ($P \leq 0.05$) among the

Table 2. *Percent frequency of occurrence of organochlorine residues in eggs of Alaskan seabirds (all species combined), by region and collection site, 1973–76.*[a]

		Residues										
Region and collection site	No. of samples	DDD	DDT	Dieldrin	Heptachlor epoxide	Mirex	Oxychlordane	Cis-chlordane[b]	Cis-nonachlor	HCB	Toxaphene	Frequency index[c]
Gulf of Alaska												
Copper River Delta	36	30.6	2.8	55.6	33.3	11.1	47.2	22.2	13.9	97.2	0.0	0.385
Hinchinbrook Island	30	70.0	36.7	76.7	83.3	46.7	100.0	70.0	36.7	93.3	20.0	0.641
Middleton Island	41	48.8	46.3	65.9	63.4	0.0	95.1	68.3	34.1	2.4	46.3	0.518
Barren Islands	16	81.3	56.3	100.0	68.8	56.3	100.0	93.7	68.7	93.8	0.0	0.707
Amalik Bay	5	0.0	20.0	100.0	60.0	0.0	80.0	20.0	20.0	80.0	0.0	0.446
Kodiak Island	47	46.8	36.2	76.6	70.2	8.5	95.7	61.7	27.7	68.1	53.2	0.573
Ugamshak Island	59	45.8	15.3	52.5	55.9	17.0	78.0	59.3	49.1	94.9	40.7	0.545
Semidi Islands	33	78.8	75.8	51.5	45.5	54.6	93.9	39.4	18.2	84.9	3.0	0.573
Shumagin Islands	16	56.3	31.3	62.3	68.8	37.5	81.3	62.5	12.5	93.8	18.8	0.558
Total	283	52.6	34.3	65.4	59.7	23.0	85.2	56.5	32.5	75.6	27.6	0.547
Aleutian Islands												
Bogoslof Island	10	10.0	20.0	90.0	40.0	30.0	90.0	10.0	40.0	90.0	0.0	0.477
Buldir Island	45	48.9	42.2	26.7	37.8	31.1	57.8	60.0	46.7	91.1	62.2	0.542
Attu Island	6	66.7	0.0	100.0	66.7	0.0	100.0	50.0	0.0	100.0	83.3	0.590
Total	61	44.3	34.4	44.3	41.0	27.9	67.2	50.8	41.0	91.8	54.1	0.536
Bristol Bay												
Round Island	10	0.0	0.0	100.0	40.0	20.0	80.0	0.0	60.0	90.0	0.0	0.454
Shaiak Island	20	25.0	15.0	90.0	60.0	40.0	75.0	35.0	75.0	95.0	0.0	0.546
Total	30	16.7	10.0	93.3	53.3	33.3	76.7	23.3	70.0	93.3	0.0	0.515
Pribilof Islands												
St. George Island	17	88.2	94.1	70.6	82.3	11.8	100.0	11.8	11.8	100.0	88.2	0.601
St. Paul Island	20	5.0	0.0	35.0	70.0	0.0	100.0	5.0	10.0	100.0	90.0	0.473
Total	37	43.2	43.2	51.3	75.7	7.5	100.0	8.1	10.8	100.0	89.2	0.559
Seward Peninsula												
Bluff Seabird Cliffs	19	57.9	0.0	15.8	42.1	10.5	100.0	42.1	26.3	100.0	0.0	0.457
King Island	10	70.0	0.0	40.0	70.0	10.0	100.0	40.0	20.0	100.0	20.0	0.515
Total	29	62.1	0.0	24.1	51.7	10.3	100.0	41.4	24.1	100.0	6.9	0.477
Grand Total	440	48.9	31.1	60.5	57.5	22.0	84.3	48.4	33.9	82.7	33.2	0.540

[a] In addition to compounds listed here, DDE was found in all samples and PCB's were detected in all eggs except five from the Copper River Delta (i.e., they were present in 86.1% of the samples from that site). Endrin occurred in one sample from Middleton Island.

[b] Or *trans*-nonachlor, or both (see Methods).

[c] Computed as total occurrences/possible occurrences. Total occurrences = number of times any of the 13 organochlorines were detected in eggs from that region or site; possible occurrences = number of clutches from that region or site × 13 chemicals.

mean concentrations of these chemicals in eggs of the same species from the different sites (or from different regions) and among different species from the same site (or region).

Organochlorine Residues

Nineteen species were represented by a total of 440 clutches of eggs (Table 1; this table also shows common and scientific names of birds mentioned in the text). Most eggs were collected in 1976 (250 clutches), but some were collected in each of the preceding 3 years (45 in 1973; 54 in 1974; 91 in 1975).

The most commonly detected pollutant in all species combined was DDE; PCB's were second, and oxychlordane and HCB were about equal in prevalence and the third and fourth most common (Table 2). Endrin was found in only one egg (that of a black-legged kittiwake), but all of the 12 other chemicals occurred in at least 22% of the total samples. Both frequency of occurrence and concentration of residues in the eggs differed geographically and by species.

In Table 2, as well as in certain other tables referred to later, data for different sites or species have been combined to reflect regional patterns in residue frequency and concentration. Other tables and Appendix III present data in greater detail (including 95% confidence intervals) to enable comparisons among collection sites within species and among species within individual sites for each chemical. These comparisons by individual site and species are the more valid biologically and statistically, but they become more meaningful when compared with the overall regional patterns that are described.

Mean concentrations of eight of the organochlorines were highest in eggs of glaucous-winged gulls from three sites (Appendix III): DDE (5.16 ppm), dieldrin (0.214 ppm), oxychlordane (0.251 ppm), and PCB's (3.55 ppm) in eggs from Bogoslof Island; heptachlor epoxide (0.037 ppm), *cis*-chlordane (0.075 ppm), and HCB (0.188 ppm) in eggs from Buldir Island; and *cis*-nonachlor (0.026 ppm) in eggs from the Semidi Islands. (*Cis*-nonachlor was nearly as high – 0.023 ppm – in eggs of ancient murrelets from Buldir Island.)

Highest concentrations of DDD (0.157 ppm), DDT (0.140 ppm), and toxaphene (0.101 ppm) were in fork-tailed storm-petrel eggs from Buldir Island, and the highest concentration of mirex (0.044 ppm) was in fork-tailed storm-petrel eggs from the Barren Islands (Appendix III). The concentration of DDD was 0.155 ppm in fork-tailed storm-petrel eggs from the Barren Islands, and the single common loon egg from Kodiak Island contained 0.120 ppm toxaphene.

Geographic Differences

Frequency of Residue Occurrence by Regions and Collection Sites

Considering all chemicals and all species, organochlorine residues occurred more frequently in eggs from the Pribilof Islands (frequency index 0.559) than in eggs from any other region; however, only three species were represented in the collection from the Pribilofs. (The frequency index represents the actual number of residue occurrences as a proportion of the possible occurrences, computed as shown in footnote c of Table 2.) Detectable residues also were more frequent in eggs from the Gulf of Alaska colonies (0.547) than in all regions combined (0.540). Frequency of residues was lowest in eggs from the Seward Peninsula (0.477).

Residues of DDE were detected in every egg we analyzed. The frequency of DDD was relatively high in eggs from the Seward Peninsula (Table 2), and it was found in more than 60% of the eggs (all species combined) at six widely separated sites divided among three regions. It was not detected in samples from Amalik Bay (Gulf of Alaska) and Round Island (Bristol Bay). Residues of DDT were not detected in Seward Peninsula samples; they were found most frequently in eggs from the Pribilof Islands. DDT occurred in more than 40% of the eggs from Middleton Island, the Barren Islands, and Semidi Islands (Gulf of Alaska); Buldir Island (Aleutian Islands); and St. George Island (Pribilofs), but it was not detected in any of the samples from Attu Island (Aleutians), Round Island, St. Paul Island (Pribilofs), or the Bluff Seabird Cliffs or King Island (Seward Peninsula). The difference in frequency of DDD and DDT in samples from the Pribilof Islands of St. George (88% and 94%) and St. Paul (5% and 0%) was readily apparent.

Dieldrin, mirex, and *cis*-nonachlor occurred most often in the samples from Bristol Bay (Table 2). Dieldrin was detected in 90% of the total samples from Bogoslof Island (Aleutians) and Shaiak Island (Bristol Bay) and in all samples from the Barren Islands, Amalik Bay, Attu Island, and Round Island. It was detected in at least 15% of the samples from every site at which eggs were collected. Mirex occurred in more than 35% of the samples from five sites, but was not detected in any of the samples from Middleton Island, Amalik Bay, Attu Island, or St. Paul Island. *Cis*-nonachlor was found in at least 40% of the eggs from six sites, and in at least 10% of those from all others except Attu Island, where it was not detected.

Heptachlor epoxide was found in more than 80% of the eggs from Hinchinbrook Island (Gulf of Alaska) and St. George Island, and in about 70% of those from six other sites (Table 2). The lowest frequency was in samples from the Copper River Delta (Gulf of Alaska).

Oxychlordane was detected in all of the eggs from the Pribilof Islands and Seward Peninsula, but the frequency of *cis*-chlordane in those samples was lower than the overall average for this chemical (Table 2). Oxychlordane was detected in every sample from three widely separated sites (Hinchinbrook Island, Barren Islands, and Attu Island; Table 2), and in those from the Pribilof Islands (St. George and St. Paul islands) or Seward Peninsula (Bluff Seabird Cliffs, King Island). The lowest frequency was in eggs from the Copper River Delta. *Cis*-chlordane occurred in at least 60% of the eggs from six sites, all of which are in the Gulf of Alaska and Aleutian Islands (Table 2). Round Island was the only site at which it was not detected in any samples.

Residues of HCB were less common in eggs from the Gulf of Alaska than the overall average for all regions combined (Table 2). However, HCB was detected in all of the eggs from the Pribilof Islands and Seward Peninsula. HCB occurred in all of the samples from Attu Island and in all of those from the two sites in the Pribilof Islands and the two in Seward Peninsula.

The frequency of toxaphene was highest in samples from the Pribilof Islands and the Aleutian Islands (Table 2). Toxaphene was found in more than 40% of the eggs from seven sites. It was not detected at seven others.

Endrin was found only in one egg of black-legged kittiwake from Middleton Island (Appendix III). PCB's were found in all of the samples we analyzed except for five of the glaucous-winged gull eggs from the Copper River Delta.

In certain species, the frequency of residue occurrence by regions was substantially different from the overall pattern for all species combined (Table 3). For example, the frequencies of mirex in glaucous-winged gull eggs from the Aleutian Islands (100%) was much higher than in those from the Gulf of Alaska (16.8%); for all species combined, the frequency of mirex was about the same in these two regions. The pattern was the same for oxychlordane, but the differences were not as great. Although only three clutches of eggs of black-legged kittiwake were collected in the Aleutian Islands, the frequency of most chemicals in the eggs that were analyzed was usually higher (often 100%) than in eggs from other regions. In the common murre, unlike most other species, the frequency of organochlorines in eggs from the Aleutian Islands and Bristol Bay was less than in eggs from the Seward Peninsula. In thick-billed murres, the frequency of residues was higher in eggs from the Seward Peninsula than in those from the Gulf of Alaska or the Aleutian Islands.

Among the individual sites with two or more species represented, the frequency of organochlorine residue oc-

Table 3. *Percent frequency of occurrence of organochlorine residues in eggs of Alaskan seabirds, 1973–76, by species within regions.*[a]

Region and species	No. of samples	Residues: DDD	DDT	Dieldrin	Heptachlor epoxide	Mirex	Oxychlordane	Cis-chlordane[b]	Cis-nonachlor	HCB	Toxaphene	Frequency index[c]
Gulf of Alaska												
Common loon	1	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	0.923
Northern fulmar	16	75.0	100.0	50.0	6.2	56.2	100.0	0.0	0.0	68.8	0.0	0.505
Fork-tailed storm-petrel	4	100.0	100.0	100.0	50.0	75.0	100.0	100.0	75.0	100.0	0.0	0.769
Double-crested cormorant	4	0.0	0.0	0.0	50.0	0.0	50.0	0.0	0.0	100.0	0.0	0.308
Pelagic cormorant	11	36.4	81.8	100.0	100.0	0.0	100.0	100.0	63.6	9.1	90.9	0.678
Red-faced cormorant	1	0.0	0.0	0.0	0.0	0.0	0.0	100.0	100.0	0.0	100.0	0.385
Glaucous-winged gull	113	46.0	23.9	79.6	68.1	16.8	78.8	53.1	20.4	81.4	18.6	0.525
Mew gull	5	80.0	60.0	100.0	100.0	0.0	100.0	40.0	40.0	0.0	0.0	0.554
Black-legged kittiwake	31	22.6	6.4	35.5	29.0	12.9	87.1	41.9	12.9	67.7	22.6	0.417
Arctic tern	3	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.231
Common murre	17	58.8	41.2	29.4	47.1	0.0	82.4	35.3	58.8	41.2	35.3	0.484
Thick-billed murre	6	0.0	0.0	33.3	50.0	0.0	83.3	16.7	0.0	83.3	0.0	0.359
Pigeon guillemot	4	0.0	0.0	25.0	0.0	0.0	50.0	25.0	75.0	100.0	100.0	0.442
Horned puffin	4	50.0	50.0	75.0	75.0	25.0	100.0	100.0	75.0	100.0	50.0	0.692
Tufted puffin	63	84.1	41.3	69.8	74.6	44.4	92.1	88.9	55.6	95.2	41.3	0.682
Total	283	52.6	34.3	65.4	59.7	23.0	85.2	56.5	32.5	75.6	27.6	0.547
Aleutian Islands												
Fork-tailed storm-petrel	7	71.4	85.7	57.1	28.6	100.0	100.0	100.0	57.1	100.0	100.0	0.769
Leach's storm-petrel	11	63.6	63.6	27.3	9.1	0.0	63.6	63.6	90.9	100.0	100.0	0.601
Pelagic cormorant	2	0.0	50.0	0.0	50.0	0.0	0.0	100.0	0.0	100.0	100.0	0.462
Aleutian Canada goose	1	0.0	0.0	100.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.308
Glaucous-winged gull	7	42.9	57.1	57.1	42.9	100.0	100.0	57.1	14.3	100.0	0.0	0.593
Black-legged kittiwake	3	100.0	100.0	0.0	100.0	100.0	100.0	100.0	33.3	100.0	0.0	0.718
Aleutian tern	6	66.7	0.0	100.0	66.7	0.0	100.0	50.0	0.0	100.0	83.3	0.590
Common murre	8	12.5	0.0	75.0	62.5	0.0	75.0	12.5	50.0	87.5	0.0	0.442
Thick-billed murre	8	0.0	0.0	0.0	0.0	0.0	12.5	0.0	0.0	100.0	0.0	0.240
Ancient murrelet	5	60.0	0.0	0.0	60.0	0.0	20.0	60.0	100.0	60.0	100.0	0.508
Horned puffin	1	100.0	0.0	100.0	0.0	0.0	100.0	100.0	0.0	0.0	100.0	0.538
Tufted puffin	2	0.0	0.0	100.0	100.0	0.0	100.0	0.0	0.0	100.0	100.0	0.538
Total	61	44.3	34.4	44.3	41.0	67.2	67.2	50.8	41.0	91.8	54.1	0.536
Bristol Bay												
Double-crested cormorant	3	33.3	0.0	100.0	66.7	0.0	66.7	0.0	100.0	100.0	0.0	0.513
Glaucous-winged gull	3	0.0	33.3	100.0	100.0	100.0	100.0	66.7	100.0	66.7	0.0	0.667
Black-legged kittiwake	9	0.0	0.0	100.0	22.2	22.2	77.8	0.0	55.6	88.9	0.0	0.436
Common murre	9	0.0	0.0	88.9	55.6	0.0	66.7	0.0	66.7	100.0	0.0	0.444
Tufted puffin	6	66.7	33.3	83.3	66.7	83.3	83.3	83.3	66.7	100.0	0.0	0.667
Total	30	16.7	10.0	93.3	53.3	33.3	76.7	23.3	70.0	93.3	0.0	0.515
Pribilof Islands												
Northern fulmar	6	83.3	100.0	83.3	50.0	33.3	100.0	33.3	33.3	100.0	100.0	0.705
Black-legged kittiwake	10	0.0	0.0	10.0	50.0	0.0	100.0	0.0	0.0	100.0	100.0	0.431
Common murre	21	52.4	47.6	61.9	95.2	0.0	100.0	4.8	9.5	100.0	81.0	0.579
Total	37	43.2	43.2	51.4	75.7	5.4	100.0	8.1	10.8	100.0	89.2	0.559
Seward Peninsula												
Black-legged kittiwake	9	22.2	0.0	22.2	44.4	22.2	100.0	44.4	33.3	100.0	0.0	0.453
Common murre	10	90.0	0.0	10.0	40.0	0.0	100.0	40.0	20.0	100.0	0.0	0.462
Thick-billed murre	10	70.0	0.0	40.0	70.0	10.0	100.0	40.0	20.0	100.0	20.0	0.515
Total	29	62.1	0.0	24.1	51.7	10.3	100.0	41.4	24.1	100.0	6.9	0.477
Grand Total	440	48.9	31.1	60.5	57.5	22.0	84.3	48.4	33.9	82.7	33.2	0.540

[a] In addition to compounds listed here, DDE was found in all samples and PCB's were detected in all eggs except five glaucous-winged gull eggs from the Gulf of Alaska (i.e., they were present in 95.6% of the samples from that region). Endrin occurred in one black-legged kittiwake egg from the Gulf of Alaska.

[b] Or *trans*-nonachlor, or both (see Methods).

[c] Computed as total occurrences/possible occurrences. Total occurrences = number of times any of the 13 organochlorines were present in eggs from that region or species; possible occurrences = number of clutches from that region or species × 13 chemicals.

currence was higher at Hinchinbrook Island, the Barren Islands, Semidi Islands, Shumagin Islands, and Kodiak (Gulf of Alaska) and St. George islands than at most other sites (Table 4). At certain sites the frequency of residue occurrence was different among the species represented; consequently the overall average for the site did not accurately reflect geographic differences among sites. For example, at the Semidi Islands the frequency of residues in glaucous-winged gull was the highest of all sites for that species, but frequencies of residues in northern fulmar and tufted puffin were the lowest for the various sites for those species; this combination produced a relatively high overall index for the site.

Frequency of residue occurrence was low (<0.500) at four sites where two or more species were sampled (Bogoslof, Round, and St. Paul islands, and the Bluff Seabird

Table 4. *Frequencies of organochlorine residues (as frequency indices[a]) in eggs of Alaskan seabirds, 1973–76, by species and collection site*

Region and collection site	CL	NF	FTSP	LSP	DCC	PC	RFC	ACG	GWG	MG	BLK	ArT	AlT	CM	TBM	PG	AM	HP	TP	Total
Gulf of Alaska																				
Copper River Delta									0.385											0.385
Hinchinbrook Island									0.638		0.400								0.815	0.641
Middleton Island						[illegible]			0.554		0.285			0.538						0.518
Barren Islands			[illegible]						0.577									0.692	0.712	0.707
Amalik Bay									0.446											0.446
Kodiak Island	[illegible]								0.602	0.554	0.490	0.231							0.692	0.573
Ugaiushak Island					[illegible]				0.586					0.407	0.350	0.442		0.692	0.671	0.545
Semidi Islands		[illegible]					0.385		0.715										0.527	0.573
Shumagin Islands									0.515										0.628	0.558
Aleutian Islands																				
Bogoslof Island									0.513					0.462						0.477
Buldir Island			[illegible]	[illegible]		0.402		0.408	0.654		0.718			[illegible]	0.240		[illegible]	0.538	0.538	0.542
[illegible] Island													0.500							0.500
Bristol Bay																				
[illegible] Island											[illegible]			0.538						[illegible]
[illegible] Island					[illegible]				0.667		0.513			0.400					0.667	0.540
Pribilof Islands																				
St. George Island		[illegible]												[illegible]						0.601
St. Paul Island											[illegible]			[illegible]						[illegible]
[illegible]																				
[illegible]											0.453			0.462						0.457
King Island															0.515					0.515
Total	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.645	0.385	0.408	0.532	0.554	0.442	0.231	0.500	0.501	0.385	0.442	0.508	0.662	0.677	0.540

[a] [illegible] number of times any of the 15 organochlorines were detected in eggs from that [illegible] 15 chemicals.

[b] CL = [illegible], NF = northern fulmar, FTSP = fork-tailed storm-petrel, LSP = Leach's storm petrel, DCC = double-crested cormorant, PC = pelagic cormorant, RFC = red-faced cormorant, ACG = Aleutian Canada goose, GWG = glaucous-winged gull, MG = mew gull, BLK = black-legged kittiwake, ArT = Arctic tern, AlT = Aleutian tern, CM = common murre, TBM = thick-billed murre, PG = pigeon guillemot, AM = ancient murrelet, HP = horned puffin, TP = tufted puffin.

[c] [illegible]

Cliffs) and at the Copper River Delta and Amalik Bay, where only glaucous-winged gull eggs were collected (Table 4). Again, however, this overall pattern did not apply to all species represented at the various sites.

Residue Concentration

Within species, there were often significant differences among regional means for DDE and PCB's (Table 5); mean residue concentrations for other chemicals were tested only among selected species and for the collection sites where adequate samples were available. Means were usually higher in the samples from the Gulf of Alaska and lower in those from the Aleutian Islands and Bristol Bay than in those from the other two regions. However, mean concentrations of both DDE and PCB's in glaucous-winged gull eggs from the Aleutian Islands were significantly higher than those from the Gulf of Alaska. Differences among the other regions were not consistent, probably in part because all of the species usually were not collected at each nesting colony.

Mean concentrations of DDE and PCB's for each species were usually of the same order of magnitude (Table 5 and Appendix III), but in black-legged kittiwake the level of DDE was consistently much the lower – usually about one-tenth that of PCB's.

Mean concentrations of DDE (5.16 ppm) and PCB's (3.55 ppm) were higher in glaucous-winged gull eggs from Bogoslof Island than in any other samples we analyzed (Appendix III). These chemicals were also somewhat higher in black-legged kittiwake (0.089 ppm DDE; 0.931 ppm PCB's) and fork-tailed storm-petrel (0.602 ppm DDE; 1.69 ppm PCB's) at Buldir Island than at the other sites where eggs of these species were collected. However, concentrations of DDE (0.119 ppm) and PCB's (0.126 ppm) were relatively low in common murres (Table 6), the only other species represented from Bogoslof Island. In thick-billed murre (PCB's only, 0.090 ppm) and tufted puffin (0.135 ppm DDE; 0.395 ppm PCB's; see also Appendix III), residue levels were lower at Buldir Island than elsewhere. (Because the sample sizes for some species were small, not all of these differences could be tested statistically; however, they indicate a pattern of relatively high residue levels in some species at Bogoslof and Buldir islands and lower levels in other species nesting there.)

Among the sites where at least five samples per species were collected, mean DDE concentrations for glaucous-winged gull eggs were highest at Kodiak Island, the Semidi Islands, and Middleton Island and lowest at the Copper River Delta, Hinchinbrook Island, the Shumagin Islands, and Ugaiushak Island (Table 6). In black-legged

Table 5. *Geometric mean DDE and PCB residue concentrations (ppm, wet weight) in eggs of Alaskan seabirds, 1973-76, ranked by region within species. Species are included only if eggs were collected in more than one region*[a]

Species and region	DDE	PCB's
Northern fulmar		
Gulf of Alaska	0.484 A	0.484 A
Pribilof Islands	0.307 A	0.387 A
Glaucous-winged gull		
Aleutian Islands	3.20 A	3.41 A
Gulf of Alaska	0.324 B	0.548 B
Black-legged kittiwake		
Gulf of Alaska	0.065 A	0.480 A
Pribilof Islands	0.033 A	0.472 A
Seward Peninsula	0.033 A	0.365 AB
Bristol Bay	0.021 A	0.204 B
Common murre		
Gulf of Alaska	0.448 A	0.625 A
Pribilof Islands	0.205 B	0.239 B
Seward Peninsula	0.141 B	0.182 B
Bristol Bay	0.134 B	0.149 B
Aleutian Islands	0.132 B	0.136 B
Thick-billed murre		
Seward Peninsula	0.166 A	0.307 A
Gulf of Alaska	0.147 A	0.259 A
Aleutian Islands	0.145 A	0.090 B
Tufted puffin		
Gulf of Alaska	0.278 A	0.518 A
Bristol Bay	0.266 A	0.423 A

[a] For each species, regional means that do not share the same letter are significantly different ($P < 0.05$) from each other (DDE and PCB's considered separately).

kittiwake there were conspicuous differences among PCB levels; higher concentrations were found at Kodiak, Middleton, and St. Paul islands and lower ones at Round and Hinchinbrook islands and the Bluff Seabird Cliffs. In common murres, both DDE and PCB's were higher at Middleton Island than at other sites. In tufted Puffins, the higher concentrations of both DDE and PCB's were in eggs from Hinchinbrook Island, and the lower ones in eggs from the Semidi Islands.

Among collection sites, there was no clear pattern in PCB/DDE ratios (Appendix III). They tended to be higher than average in one or more species at St. Paul, Ugaiushak, Middleton, and Buldir islands than at other sites, but there were often other species with low ratios at these sites.

For other chemicals, there often were also significant differences in mean concentrations among the various collection sites (Table 6). Detailed information (i.e., sample size, number with residues, geometric mean, 95% confidence interval, and range) is presented in Appendix III for each species. We were able to collect at least five eggs per site at two or more sites for six species, and comparisons can be made within species to reflect differences among the sites where they were collected (Table 6).

Northern fulmar. – Concentrations of DDT were higher at the Semidi Islands than at St. George Island; for all other chemicals in which there were significant differences, concentrations were higher in the samples from St. George Island.

Glaucous-winged gull. – Concentrations of several chemicals were higher in eggs from the Semidi Islands or Shumagin Islands, or both, than in those from other sites. However, concentrations of other chemicals tended to be relatively low at those two sites. In general, concentrations of most chemicals were among the lowest in eggs from the Copper River Delta and Amalik Bay.

Black-legged kittiwake. – Concentrations of several chemicals in eggs from Kodiak Island, and of dieldrin and mirex in eggs from Round Island, were higher than those in samples from other sites. However, the Round Island samples had among the lowest concentrations for other chemicals. Although also reflected somewhat in the other species, kittiwake eggs showed clearly the trend toward higher concentrations of HCB in the samples collected at the westernmost nesting colonies.

Common murre. – Concentrations of DDD and DDT were highest at St. George and Middleton islands and lowest at Bogoslof, St. Paul, and Shaiak islands. The significant difference between St. George and St. Paul, which are near each other, was notable.

Thick-billed murre. – Except for PCB's, there were significant geographic differences in only two chemicals (DDD and oxychlordane) in this species. Concentrations of each were highest at King Island and lowest at Buldir Island.

Tufted puffin. – Concentrations of several chemicals were higher in eggs collected at Hinchinbrook Island and the Barren Islands than in those from other sites. Concentrations of most chemicals tended to be lowest in samples from Ugaiushak, Kodiak, and Shaiak islands.

Species Differences

Among eggs of species collected in two or more regions, the frequency of residue occurrence (Table 4) was highest in those of fork-tailed storm-petrel (frequency index 0.769), tufted puffin (0.677), horned puffin (0.662), pelagic cormorant (0.645), and northern fulmar (0.559), and lowest in those of common murre (0.501), black-legged kittiwake (0.442), double-crested cormorant (0.396), and thick-billed murre (0.385). These patterns were also reflected at certain sites where at least two of these species were collected (Table 3). In some species, the frequency of occurrence was higher than for most other species in certain regions, but not overall. For example, frequencies of residues were high in eggs of glaucous-winged gulls in the Aleutian Islands (0.593) and Bristol Bay (0.667), black

Table 6. *Mean concentrations (ppm, wet weight) of organochlorines in eggs of Alaskan seabirds, 1973–76, ranked by collection site, by species and compound. Species are included only if at least five eggs were collected at each of two or more sites. Compounds are omitted if there were no significant differences (P>0.05) among sites for a particular species.*

Species, compound and site	Geometric mean[a]
Northern fulmar	
DDT	
Semidi Islands	0.048 A
St. George Island	0.015 B
Heptachlor epoxide	
St. George Island	0.005 A
Semidi Islands	<0.001 B
Oxychlordane	
St. George Island	0.0[illegible]7 A
Semidi Islands	<0.033 B
Cis-chlordane[b]	
St. George Island	0.001 A
Semidi Islands	ND[c] B
Cis-nonachlor	
St. George Island	0.003 A
Semidi Islands	ND B
HCB	
St. George Island	0.055 A
Semidi Islands	0.008 B
Toxaphene	
St. George Island	0.051 A
Semidi Islands	ND B
Glaucous-winged gull	
DDE	
Kodiak Island	0.661 A
Semidi Islands	0.559 AB
Middleton Island	0.540 AB
Amalik Bay	0.334 BC
Ugaiushak Island	0.298 C
Shumagin Islands	0.284 C
Hinchinbrook Island	0.277 C
Copper River Delta	0.116 C
DDD	
Semidi Islands	0.010 A
Hinchinbrook Island	0.007 AB
Kodiak Island	0.007 AB
Ugaiushak Island	0.005 AB
Middleton Island	0.005 AB
Copper River Delta	0.003 B
Shumagin Islands	0.002 B
Amalik Bay	ND B
DDT	
Semidi Islands	0.013 A
Kodiak Island	0.011 B
Shumagin Islands	0.006 ABC
Middleton Island	0.004 ABC
Ugaiushak Island	0.003 BC
Amalik Bay	0.001 BC
Copper River Delta	<0.001 C
Hinchinbrook Island	ND C
Dieldrin	
Amalik Bay	0.025 A
Kodiak Island	0.025 A[d]
Middleton Island	0.021 A
Shumagin Islands	0.017 AB
Semidi Islands	0.012 ABC
Ugaiushak Island	0.009 BC
Hinchinbrook Island	0.009 BC
Copper River Delta	0.005 C
Heptachlor epoxide	
Kodiak Island	0.025 A
Hinchinbrook Island	0.014 B
Semidi Islands	0.011 BC
Ugaiushak Island	0.010 BC
Middleton Island	0.010 BC
Amalik Bay	0.007 BC
Shumagin Islands	0.005 BC
Copper River Delta	0.003 C
Mirex	
Semidi Islands	0.036 A
Shumagin Islands	0.025 A
Ugaiushak Island	0.002 B
Kodiak Island	0.002 B
Copper River Delta	<0.001 B
Hinchinbrook Island	ND B
Middleton Island	ND B
Amalik Bay	ND B
Oxychlordane	
Shumagin Islands	0.031 A
Semidi Islands	0.031 A
Kodiak Island	0.024 AB
Ugaiushak Island	0.021 AB
Middleton Island	0.020 AB
Hinchinbrook Island	0.014 BC
Amalik Bay	0.008 BC
Copper River Delta	0.007 C
Cis-chlordane[b]	
Semidi Islands	0.017 A
Kodiak Island	0.013 AB
Middleton Island	0.012 AB
Hinchinbrook Island	0.011 ABC
Ugaiushak Island	0.010 ABC
Shumagin Islands	0.006 BC
Copper River Delta	0.003 C
Amalik Bay	0.001 C
Cis-nonachlor	
Semidi Islands	0.026 A
Ugaiushak Island	0.004 B
Kodiak Island	0.004 B
Amalik Bay	0.002 B
Hinchinbrook Island	0.001 B
Copper River Delta	0.001 B
Middleton Island	<0.001 B
Shumagin Islands	ND B

Table 6. Continued

Species, compound and site	Geometric mean[a]
HCB	
Shumagin Islands	0.654 A
Semidi Islands	0.040 B
Ugaiushak Island	0.031 BC
Amalik Bay	0.028 BCD
Hinchinbrook Island	0.019 CDE
Copper River Delta	0.015 DE
Kodiak Island	0.011 EF
Middleton Island	ND F
Toxaphene	
Shumagin Islands	0.013 A
Hinchinbrook Island	0.010 AB
Kodiak Island	0.008 AB[d]
Middleton Island	0.007 AB
Ugaiushak Island	0.004 AB
Copper River Delta	ND B
Amalik Bay	ND B
Semidi Islands	ND B
PCB's	
Kodiak Island	1.22 A
Middleton Island	0.941 AB
Semidi Islands	0.741 BC
Shumagin Islands	0.613 BC
Ugaiushak Island	0.609 BC
Hinchinbrook Island	0.461 CD
Amalik Bay	0.377 CD
Copper River Delta	0.194 D
Black-legged kittiwake	
Dieldrin	
Kodiak Island	0.006 A
Round Island	0.005 A
Hinchinbrook Island	0.003 AB
Middleton Island	0.001 B
Bluff Seabird Cliffs	<0.001 B
St. Paul Island	<0.001 B
Mirex	
Hinchinbrook Island	0.002 A
Round Island	0.002 A
Bluff Seabird Cliffs	0.001 AB
Middleton Island	ND B
Kodiak Island	ND B
St. Paul Island	ND B
Cis-chlordane	
Middleton Island	0.010 A
Kodiak Island	0.004 AB
Bluff Seabird Cliffs	0.002 B
Hinchinbrook Island	0.001 B
Round Island	ND B
St. Paul Island	ND B
HCB	
St. Paul Island	0.043 A
Bluff Seabird Cliffs	0.031 B
Kodiak Island	0.023 BC
Hinchinbrook Island	0.018 C
Round Island	0.018 C
Middleton Island	ND D

Species, compound and site	Geometric mean[a]
Toxaphene	
St. Paul Island	0.025 A
Kodiak Island	0.005 B
Middleton Island	0.002 BC
Hinchinbrook Island	ND C
Round Island	ND C
Bluff Seabird Cliffs	ND C
PCB's	
Kodiak Island	0.610 A
Middleton Island	0.539 AB
St. Paul Island	0.472 ABC
Bluff Seabird Cliffs	0.365 BCD
Hinchinbrook Island	0.296 CD
Round Island	0.187 D
Common murre	
DDE	
Middleton Island	0.649 A
St. George Island	0.273 B
Ugaiushak Island	0.202 B
Shaiak Island	0.153 B
Bluff Seabird Cliffs	0.141 B
St. Paul Island	0.135 B
Bogoslof Island	0.119 B
DDD	
St. George Island	0.035 A
Middleton Island	0.033 A
Bluff Seabird Cliffs	0.010 B
Ugaiushak Island	0.002 B
Bogoslof Island	0.001 B
St. Paul Island	<0.001 B
Shaiak Island	ND B
DDT	
Middleton Island	0.017 A
St. George Island	0.013 A
Ugaiushak Island	0.002 B
Bluff Seabird Cliffs	ND B
Bogoslof Island	ND B
St. Paul Island	ND B
Shaiak Island	ND B
Dieldrin	
Bogoslof Island	0.034 A
Middleton Island	0.026 AB
Shaiak Island	0.012 AB
St. George Island	0.009 AB
St. Paul Island	0.005 AB
Bluff Seabird Cliffs	<0.001 B
Ugaiushak Island	ND B
Heptachlor epoxide	
St. George Island	0.012 A
Middleton Island	0.011 A
St. Paul Island	0.011 AB
Ugaiushak Island	0.005 AB
Bogoslof Island	0.004 AB
Bluff Seabird Cliffs	0.004 B
Shaiak Island	0.004 B

Table 6. Continued

Species, compound and site	Geometric mean[a]
Oxychlordane	
Middleton Island	0.042 A
St. Paul Island	0.026 B
Bluff Seabird Cliffs	0.023 B
St. George Island	0.018 B
Ugaiushak Island	0.008 C
Bogoslof Island	0.005 C
Shaiak Island	0.002 C
Cis-chlordane[b]	
Middleton Island	0.012 A
Bluff Seabird Cliffs	0.003 B
Ugaiushak Island	0.002 B
Bogoslof Island	<0.001 B
St. Paul Island	<0.001 B
Shaiak Island	ND B
St. George Island	ND B
Cis-nonachlor	
Ugaiushak Island	0.014 A
Middleton Island	0.008 AB
Bogoslof Island	0.008 ABC
Shaiak Island	0.002 BC
St. Paul Island	0.002 BC
Bluff Seabird Cliffs	0.001 BC
St. George Island	ND C
HCB	
Bluff Seabird Cliffs	0.111 A
Shaiak Island	0.100 AB
St. Paul Island	0.080 B
St. George Island	0.079 B
Bogoslof Island	0.066 B
Ugaiushak Island	0.027 C
Middleton Island	ND D
Toxaphene	
St. George Island	0.037 A
Middleton Island	0.023 AB
St. Paul Island	0.019 AB
Ugaiushak Island	0.014 AB
Bogoslof Island	ND B
Shaiak Island	ND B
Bluff Seabird Cliffs	ND B
PCB's	
Middleton Island	1.05 A
St. George Island	0.270 B
St. Paul Island	0.205 B
Bluff Seabird Cliffs	0.182 B
Ugaiushak Island	0.168 B
Shaiak Island	0.147 B
Bogoslof Island	0.126 B
Thick-billed murre	
DDD	
King Island	0.009 A
Ugaiushak Island	ND B
Buldir Island	ND B
Oxychlordane	
King Island	0.021 A
Ugaiushak Island	0.019 A
Buldir Island	<0.001 B
PCB's	
King Island	0.307 A
Ugaiushak Island	0.259 A
Buldir Island	0.090 B
Tufted puffin	
DDE	
Hinchinbrook Island	0.408 A
Shumagin Islands	0.368 AB
Kodiak Island	0.339 AB
Barren Islands	0.297 AB
Shaiak Island	0.266 BC
Ugaiushak Island	0.205 C
Semidi Islands	0.162 C
DDD	
Hinchinbrook Island	0.033 A
Shumgain Islands	0.024 AB
Barren Islands	0.024 AB
Semidi Islands	0.023 AB
Ugaiushak Island	0.016 BC
Kodiak Island	0.008 C
Shaiak Island	0.005 C
DDT	
Hinchinbrook Island	0.025 A
Shumagin Islands	0.014 AB
Barren Islands	0.011 B
Semidi Islands	0.008 B
Kodiak Island	0.002 B
Ugaiushak Island	0.002 B
Shaiak Island	0.002 B
Dieldrin	
Barren Islands	0.026 A
Shaiak Island	0.020 A
Hinchinbrook Island	0.020 A
Kodiak Island	0.016 AB
Ugaiushak Island	0.008 B
Shumagin Islands	0.005 B
Semidi Islands	0.004 B
Heptachlor epoxide	
Kodiak Island	0.012 A
Hinchinbrook Island	0.011 AB
Shumagin Islands	0.009 ABC
Semidi Islands	0.007 ABCD
Barren Islands	0.006 BCD
Shaiak Island	0.004 CD
Ugaiushak Island	0.004 D[d]
Mirex	
Hinchinbrook Island	0.014 A
Ugaiushak Island	0.007 AB
Shaiak Island	0.006 AB
Barren Islands	0.003 AB
Semidi Islands	0.002 AB
Shumagin Islands	0.002 AB
Kodiak Island	0.001 B

Table 6. Continued

Species, compound and site	Geometric mean[a]
Cis-chlordane[b]	
Barren Islands	0.030 A
Hinchinbrook Island	0.023 AB
Shumagin Islands	0.018 ABC
Semidi Islands	0.014 BC
Ugaiushak Island	0.013 C
Kodiak Island	0.012 C
Shaiak Island	0.008 C
Cis-nonachlor	
Hinchinbrook Island	0.014 A
Barren Islands	0.009 AB
Shaiak Island	0.006 B
Ugaiushak Island	0.006 B[d]
Semidi Islands	0.004 B
Kodiak Island	0.003 B
Shumagin Islands	0.003 B
HCB	
Shaiak Island	0.064 A
Shumagin Islands	0.037 B
Hinchinbrook Island	0.036 B
Barren Islands	0.033 B
Semidi Islands	0.032 B
Ugaiushak Island	0.029 B
Kodiak Island	0.024 B
Toxaphene	
Kodiak Island	0.065 A
Shumagin Islands	0.018 B
Ugaiushak Island	0.015 B
Semidi Islands	0.003 B
Hinchinbrook Island	ND B
Barren Islands	ND B
Shaiak Island	ND B
PCB's	
Hinchinbrook Island	0.625 A
Barren Islands	0.574 A
Kodiak Island	0.533 A
Ugaiushak Island	0.531 A
Shumagin Islands	0.524 AB
Shaiak Island	0.423 AB
Semidi Islands	0.263 B

[a] For each species, means that do not share the same letter are significantly different ($P < 0.05$) from each other (each compound considered separately).

[b] Or *trans*-nonachlor, or both (see Methods).

[c] ND = not detected in these samples.

[d] Mean reflects collections in two years with differences among years; see Appendix III.

legged kittiwakes in the Aleutian Islands (0.718), and common murres in the Pribilof Islands (0.579), although the average for these species for all regions was low.

Mean concentrations of DDE and PCB's on a regional basis varied significantly among species, but there were few consistent patterns of species differences (Table 7). However, black-legged kittiwakes (when they were represented) always had the lowest levels of DDE, and murres usually had low concentrations of PCB's. Northern fulmars usually were in the group that had higher concentrations of both chemicals (except PCB's in the Gulf of Alaska) than other species, and glaucous-winged gulls in the Aleutian Islands had concentrations of both DDE and PCB's that were clearly higher than those in the other species.

Frequency of Residue Occurrence by Species

Residues of DDT and oxychlordane were found in each of the northern fulmar eggs (Table 3), whereas the frequency of these chemicals was lower in other species (except for oxychlordane in the Pribilof Islands) where the fulmar eggs were taken. For heptachlor epoxide, *cis*-chlordane, and *cis*-nonachlor, frequency of occurrence in the fulmar eggs was lower than the average for all species combined.

Except for DDE, heptachlor epoxide, and toxaphene (in the Gulf of Alaska only), frequencies of all chemicals in fork-tailed storm-petrel eggs were considerably higher than the average for all species (Table 3). In Leach's storm-petrel the frequency of most chemicals (except *cis*-chlordane and those found in all storm-petrel eggs) was somewhat lower than in fork-tailed storm-petrels. However, frequency of DDD, DDT, *cis*-chlordane, *cis*-nonachlor, HCB, and toxaphene in Leach's storm-petrel eggs was above the average for all species in the Aleutian Islands. Mirex and endrin were the only chemicals not detected in petrels.

Frequencies of most chemicals were low in cormorant eggs from most regions (Table 3); however, we were usually not able to collect a series of eggs large enough to enable sound comparisons. The exception was for pelagic cormorants from the Gulf of Alaska, where eggs from 11 clutches were collected. In those eggs, the frequency of DDD and HCB was lower than the averages for all species from that region, but the frequency for other chemicals was at least as great as the overall average.

In the Gulf of Alaska, the frequency of DDD, DDT, mirex, oxychlordane, *cis*-nonachlor, and toxaphene was slightly lower in glaucous-winged gull eggs than in all species combined (Table 3), and five of the gull eggs from

Table 7. *Mean DDE and PCB residue concentrations (ppm, wet weight) in eggs of Alaskan seabirds, 1973–76, ranked by species within regions. Species are included only if five or more samples were collected in that region.*

DDE			PCB's	
Species	Geometric mean[a]	Site	Species	Geometric mean[a]
		Gulf of Alaska		
Mew gull	0.660 A		Mew gull	3.34 A
Northern fulmar	0.484 AB		Common murre	0.625 B
Common murre	0.448 AB		Glaucous-winged gull	0.548 B
Glaucous-winged gull	0.324 BC		Tufted puffin	0.518 B
Tufted puffin	0.278 CD		Northern fulmar	0.484 B
Thick-billed murre	0.147 CDE		Black-legged kittiwake	0.480 B
Pelagic cormorant	0.134 DE		Pelagic cormorant	0.296 B
Black-legged kittiwake	0.065 E		Thick-billed murre	0.259 B
		Aleutian Islands		
Glaucous-winged gull	3.29 A		Glaucous-winged gull	3.41 A
Ancient murrelet	1.61 B		Fork-tailed storm-petrel	1.69 B
Fork-tailed storm-petrel	0.602 BC		Ancient murrelet	0.829 BC
Aleutian tern	0.432 C		Leach's storm-petrel	0.508 CD
Leach's storm-petrel	0.337 C		Aleutian tern	0.325 CD
Thick-billed murre	0.145 C		Common murre	0.136 D
Common murre	0.132 C		Thick-billed murre	0.090 D
		Bristol Bay		
Tufted puffin	0.266 A		Tufted puffin	0.423 A
Common murre	0.134 B		Black-legged kittiwake	0.204 B
Black-legged kittiwake	0.021 C		Common murre	0.149 B
		Pribilof Islands		
Northern fulmar	0.307 A		Black-legged kittiwake	0.472 A
Common murre	0.205 A		Northern fulmar	0.387 A
Black-legged kittiwake	0.033 B		Common murre	0.239 B
		Seward Peninsula		
Thick-billed murre	0.166 A		Black-legged kittiwake	0.365 A
Common murre	0.141 A		Thick-billed murre	0.307 A
Black-legged kittiwake	0.033 B		Common murre	0.182 B

[a] For each region, species means that do not share the same letter are significantly different ($P < 0.05$) from each other (DDE and PCB's considered separately

this region were the only samples in which PCB's were not detected. Except for *cis*-nonachlor and toxaphene in the glaucous-winged gull eggs from the Aleutian Islands, the occurrence of other chemicals was near or above the overall average.

Almost all chemicals were consistently less common in black-legged kittiwake eggs than the average for all species (Table 3). Among the few exceptions to this pattern were the prevalence of many chemicals in the kittiwake eggs from the Aleutian Islands, and the slightly higher-than-average occurrence of dieldrin in eggs from Bristol Bay and mirex in those from the Seward Peninsula. This is the only species in which residues of all 13 organochlorines were detected.

The frequency of residue occurrence in common murre eggs was usually less than the average for all species in each region (Table 3). However, in the Pribilof Islands DDD, DDT, dieldrin, and heptachlor epoxide occurred more commonly in this species than the average for all species. Mirex and endrin were the only organochlorines not detected in common murre eggs.

In tufted puffin eggs, the frequency of many chemicals was notably higher than the average for all species (Table 3). For example, DDD, heptachlor epoxide, mirex, *cis*-chlordane, *cis*-nonachlor, HCB, and toxaphene were commonly detected in the tufted puffin eggs from the Gulf of Alaska, and the frequency of DDD, mirex, and *cis*-chlordane was high in those from Bristol Bay.

Residue Concentration

The differences in residue concentration among species were not distinct, in part because of the differences in species composition of egg collections, as well as in levels of exposure or other factors at the various sites. Mean concentrations for all chemicals are presented in Appendix III, and selected comparisons are shown in Table 8.

There were significant differences among species-mean DDE concentrations at seven sites (Table 8). At those sites, and at others where the differences were not significant, DDE residue concentrations usually were higher in eggs of glaucous-winged gull, tufted puffin, northern fulmar, and common murre than in those of other species, and usually were lower in eggs of black-legged kittiwake, thick-billed murre, horned puffin, and cormorant than in those of other species that were well enough represented in the samples to enable sound comparisons.

Species-mean PCB concentrations were significantly different at nine sites (Table 8). Concentrations of PCB residues in eggs usually were higher in glaucous-winged gull and tufted puffin, and lower in common murre, black-legged kittiwake, and cormorant, than in most other species; however, this pattern was not consistent.

Eggs of ancient murrelet and storm-petrel (both species) were compared only at Buldir Island; they contained higher mean concentrations of both DDE and PCB's than most other species sampled there.

The PCB/DDE ratio was usually lower (less than 2.0) in eggs of northern fulmar, glaucous-winged gull, murre, and tufted puffin than in those of other species (Appendix III). The ratio was much higher (often greater than 10.0) in black-legged kittiwake than in other species.

Mean concentrations of other chemicals also often differed significantly among the various species. Detailed information (i.e., sample size, number with residues, geometric mean, 95% confidence interval, and range) is presented in Appendix III for each species and collection site. We collected at least five eggs per species for two or more species at 11 sites. Statistical comparisons of species-means for each of these sites are summarized here and in Table 8.

Hinchinbrook Island. – Residues of DDD, DDT, dieldrin, mirex, *cis*-chlordane, *cis*-nonachlor, and HCB were higher in tufted puffin eggs than in those of glaucous-winged gull or black-legged kittiwake, and for dieldrin, heptachlor epoxide, and *cis*-chlordane, levels in kittiwake eggs were significantly lower than those in the glaucous-winged gull eggs. Toxaphene was highest in glaucous-winged gull eggs, but there was no difference between the concentrations in kittiwake and puffin eggs.

Middleton Island. – Residues of DDD, DDT, heptachlor epoxide, and oxychlordane were highest in common murre eggs and lowest in pelagic cormorant and black-legged kittiwake eggs. *Cis*-chlordane and toxaphene were significantly higher in pelagic cormorant eggs than in those of any other species, and *cis*-nonachlor in eggs was significantly higher in common murre than in glaucous-winged gull.

Kodiak Island. – Residues of DDT were higher in eggs of glaucous-winged gull than in black-legged kittiwake, and dieldrin was higher in mew gull and glaucous-winged gull than in kittiwake. Heptachlor epoxide was higher in glaucous-winged gull eggs than in those of other species. HCB was higher in tufted puffin and black-legged kittiwake than in either gull species, and toxaphene was higher in tufted puffin than in any of the other species.

Ugaiushak Island. – DDD in eggs was significantly higher in tufted puffin than in any other species, and *cis*-chlordane was higher in tufted puffin than in murres. However, *cis*-nonachlor in common murres and HCB in thick-billed murres were higher than in the other species. Heptachlor epoxide was significantly higher in glaucous-winged gull eggs than in those of tufted puffins, and oxychlordane was higher in glaucous-winged gull eggs than in tufted puffin and common murre eggs.

Semidi Islands. – DDD in eggs was significantly higher in tufted puffins than in glaucous-winged gulls or northern fulmars; dieldrin and mirex were significantly higher in gulls than in either of the other species. Residues of DDT were higher in northern fulmar eggs than in gull or puffin eggs. Concentrations of heptachlor epoxide, *cis*-chlordane, and HCB in eggs were significantly higher in glaucous-winged gull and tufted puffin than in the fulmar.

Shumagin Islands. – DDD and *cis*-chlordane were significantly higher in tufted puffin eggs than in glaucous-winged gull eggs, but there were no significant differences in residues among eggs of these species in any of the other chemicals.

Buldir Island. – DDD, DDT, dieldrin, mirex, oxychlordane, *cis*-chlordane, and toxaphene were significantly higher in eggs of fork-tailed storm-petrel than in those of Leach's storm-petrel, ancient murrelet, or thick-billed murre. Toxaphene in eggs was also higher in Leach's storm-petrels than in thick-billed murres, but there were no other significant differences among these species for these chemicals. Heptachlor epoxide and *cis*-nonachlor were higher in ancient murrelets than in any of the other species, and *cis*-nonachlor also was higher in eggs of Leach's storm-petrels than in those of fork-tailed storm-petrels or thick-billed murres. However, the concentration of HCB in eggs was higher in thick-billed murre than in ancient murrelet.

Shaiak Island. – Mirex and *cis*-chlordane were significantly higher in tufted puffin than in common murre eggs, but there were no significant differences between those species for the other chemicals.

St. George Island. – Concentrations of DDD and heptachlor epoxide were higher in eggs of common murres than in those of northern fulmars, but levels of oxychlordane, *cis*-chlordane, and *cis*-nonachlor were higher in eggs of the fulmar than in those of the murre.

St. Paul Island. – Dieldrin, heptachlor epoxide, and HCB were significantly higher in common murre than in black-legged kittiwake eggs; oxychlordane was higher in the kittiwakes than in the murres.

Bluff Seabird Cliffs. – Concentrations of DDD, oxychlordane, and HCB in eggs were significantly higher in common murre than in black-legged kittiwake.

Table 8. *Mean concentrations (ppm, wet weight) of organochlorines in eggs of Alaskan seabirds, 1973–76, ranked by species within collection site and compound. Sites are included only if at least five eggs were collected for each of two or more species. Compounds are omitted if there were no significant differences (P < 0.05) among species at a particular site*

Site, compound and species	Geometric mean[a]
Hinchinbrook Island	
DDE	
Tufted puffin	0.408 A
Glaucous-winged gull	0.277 A
Black-legged kittiwake	0.074 B
DDD	
Tufted puffin	0.033 A
Glaucous-winged gull	0.007 B
Black-legged kittiwake	0.004 B
DDT	
Tufted puffin	0.025 A
Black-legged kittiwake	0.002 B
Glaucous-winged gull	ND[b] B
Dieldrin	
Tufted puffin	0.020 A
Glaucous-winged gull	0.009 B
Black-legged kittiwake	0.003 C
Heptachlor epoxide	
Glaucous-winged gull	0.014 A
Tufted puffin	0.011 A
Black-legged kittiwake	0.003 B
Mirex	
Tufted puffin	0.014 A
Black-legged kittiwake	0.002 B
Glaucous-winged gull	ND B
Oxychlordane	
Tufted puffin	0.017 A
Glaucous-winged gull	0.014 AB
Black-legged kittiwake	0.009 B
Cis-chlordane[c]	
Tufted puffin	0.023 A
Glaucous-winged gull	0.011 B
Black-legged kittiwake	0.001 C
Cis-nonachlor	
Tufted puffin	0.014 A
Glaucous-winged gull	0.001 B
Black-legged kittiwake	<0.001 B
HCB	
Tufted puffin	0.036 A
Glaucous-winged gull	0.019 B
Black-legged kittiwake	0.018 B
Toxaphene	
Glaucous-winged gull	0.010 A
Black-legged kittiwake	ND B
Tufted puffin	ND B
PCB's	
Tufted puffin	0.625 A
Glaucous-winged gull	0.461 A
Black-legged kittiwake	0.296 B

Site, compound and species	Geometric mean[a]
Middleton Island	
DDE	
Common murre	0.649 A
Glaucous-winged gull	0.540 A
Pelagic cormorant	0.134 B
Black-legged kittiwake	0.047 B
DDD	
Common murre	0.033 A
Glaucous-winged gull	0.005 B
Pelagic cormorant	0.003 B
Black-legged kittiwake	<0.001 B
DDT	
Common murre	0.017 A
Pelagic cormorant	0.005 B
Glaucous-winged gull	0.004 B
Black-legged kittiwake	ND B
Heptachlor epoxide	
Common murre	0.011 A
Glaucous-winged gull	0.010 A
Pelagic cormorant	0.007 AB
Black-legged kittiwake	ND B
Oxychlordane	
Common murre	0.042 A
Glaucous-winged gull	0.020 B
Black-legged kittiwake	0.009 C
Pelagic cormorant	0.009 C
Cis-chlordane[c]	
Pelagic cormorant	0.032 A
Common murre	0.012 B
Glaucous-winged gull	0.012 B
Black-legged kittiwake	0.010 B
Cis-nonachlor	
Common murre	0.008 A
Pelagic cormorant	0.005 AB
Black-legged kittiwake	0.002 AB
Glaucous-winged gull	<0.001 B
Toxaphene	
Pelagic cormorant	0.081 A
Common murre	0.023 B
Glaucous-winged gull	0.007 B
Black-legged kittiwake	0.002 B
PCB's	
Common murre	1.05 A
Glaucous-winged gull	0.941 A
Black-legged kittiwake	0.539 AB
Pelagic cormorant	0.296 B

Table 8. Continued

Site, compound and species	Geometric mean[a]
Kodiak Island	
DDE	
Glaucous-winged gull	0.661 A
Mew gull	0.660 A
Tufted puffin	0.339 AB
Black-legged kittiwake	0.073 B
DDT	
Glaucous-winged gull	0.011 A
Mew gull	0.005 AB
Tufted puffin	0.002 AB
Black-legged kittiwake	< 0.001 B
Dieldrin	
Mew gull	0.025 A
Glaucous-winged gull	0.025 A[d]
Tufted puffin	0.016 AB
Black-legged kittiwake	0.006 B
Heptachlor epoxide	
Glaucous-winged gull	0.025 A
Tufted puffin	0.012 B
Mew gull	0.010 B
Black-legged kittiwake	0.003 B
HCB	
Tufted puffin	0.024 A
Black-legged kittiwake	0.023 A
Glaucous-winged gull	0.011 B
Mew gull	ND C
Toxaphene	
Tufted puffin	0.065 A
Glaucous-winged gull	0.008 B[d]
Black-legged kittiwake	0.005 B
Mew gull	ND B
PCB's	
Mew gull	3.34 A
Glaucous-winged gull	1.22 B
Black-legged kittiwake	0.610 C
Tufted puffin	0.533 C
Ugashak Island	
DDD	
Tufted puffin	0.016 A
Glaucous-winged gull	0.005 B
Common murre	0.002 B
Thick-billed murre	ND B
Heptachlor epoxide	
Glaucous-winged gull	0.010 A
Thick-billed murre	0.007 AB
Common murre	0.005 AB
Tufted puffin	0.004 B[d]
Oxychlordane	
Glaucous-winged gull	0.021 A
Thick-billed murre	0.019 AB
Tufted puffin	0.009 B
Common murre	0.008 B
Cis-chlordane[c]	
Tufted puffin	0.013 A
Glaucous-winged gull	0.010 AB
Thick-billed murre	0.003 BC
Common murre	0.002 C
Cis-nonachlor	
Common murre	0.014 A
Tufted puffin	0.006 B[d]
Glaucous-winged gull	0.004 B
Thick-billed murre	ND B
HCB	
Thick-billed murre	0.060 A
Glaucous-winged gull	0.031 B
Tufted puffin	0.029 B
Common murre	0.027 B
PCB's	
Glaucous-winged gull	0.609 A
Tufted puffin	0.531 A
Thick-billed murre	0.259 AB
Common murre	0.168 B
Semidi Islands	
DDE	
Glaucous-winged gull	0.559 A
Northern fulmar	0.484 A
Tufted puffin	0.162 B
DDD	
Tufted puffin	0.023 A
Glaucous-winged gull	0.010 B
Northern fulmar	0.007 B
DDT	
Northern fulmar	0.048 A
Glaucous-winged gull	0.013 B
Tufted puffin	0.008 B
Dieldrin	
Glaucous-winged gull	0.012 A
Northern fulmar	0.005 B
Tufted puffin	0.004 B
Heptachlor epoxide	
Glaucous-winged gull	0.011 A
Tufted puffin	0.007 A
Northern fulmar	< 0.001 B
Mirex	
Glaucous-winged gull	0.036 A
Northern fulmar	0.004 B
Tufted puffin	0.002 B
Oxychlordane	
Northern fulmar	0.033 A
Glaucous-winged gull	0.031 A
Tufted puffin	0.009 B
Cis-chlordane[c]	
Glaucous-winged gull	0.017 A
Tufted puffin	0.014 A
Northern fulmar	ND B

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Table 8. Continued

Site, compound and species	Geometric mean[a]
HCB	
Glaucous-winged gull	0.040 A
Tufted puffin	0.032 A
Northern fulmar	0.008 B
PCB's	
Glaucous-winged gull	0.741 A
Northern fulmar	0.484 B
Tufted puffin	0.263 B
Shumagin Islands	
DDD	
Tufted puffin	0.024 A
Glaucous-winged gull	0.002 B
Cis-chlordane[a]	
Tufted puffin	0.018 A
Glaucous-winged gull	0.006 B
Buldir Island	
DDE	
Ancient murrelet	1.61 A
Fork-tailed storm-petrel	0.602 B
Leach's storm-petrel	0.337 C
Thick-billed murre	0.145 D
DDD	
Fork-tailed storm-petrel	0.137 A
Leach's storm-petrel	0.017 B
Ancient murrelet	0.005 B
Thick-billed murre	ND B
DDT	
Fork-tailed storm-petrel	0.140 A
Leach's storm-petrel	0.019 B
Ancient murrelet	ND B
Thick-billed murre	ND B
Dieldrin	
Fork-tailed storm-petrel	0.032 A
Leach's storm-petrel	0.002 B
Ancient murrelet	ND B
Thick-billed murre	ND B
Heptachlor epoxide	
Ancient murrelet	0.004 A
Fork-tailed storm-petrel	0.001 B
Leach's storm-petrel	< 0.001 B
Thick-billed murre	ND B
Mirex	
Fork-tailed storm-petrel	0.026 A
Leach's storm-petrel	ND B
Ancient murrelet	ND B
Thick-billed murre	ND B
Oxychlordane	
Fork-tailed storm-petrel	0.059 A
Leach's storm-petrel	0.016 B
Ancient murrelet	0.005 B
Thick-billed murre	< 0.001 B
Cis-chlordane[a]	
Fork-tailed storm-petrel	**0.053 A**
Leach's storm-petrel	**0.006 B**
Ancient murrelet	**0.006 B**
Thick-billed murre	**ND B**
Cis-nonachlor	
Ancient murrelet	0.023 A
Leach's storm-petrel	0.013 B
Fork-tailed storm-petrel	0.004 C
Thick-billed murre	ND C
HCB	
Thick-billed murre	0.062 A
Fork-tailed storm-petrel	0.041 AB
Leach's storm-petrel	0.018 AB
Ancient murrelet	0.002 B
Toxaphene	
Fork-tailed storm-petrel	0.101 A
Leach's storm-petrel	0.050 B
Ancient murrelet	0.030 BC
Thick-billed murre	ND C
PCB's	
Fork-tailed storm-petrel	1.60 A
Ancient murrelet	0.820 B
Leach's storm-petrel	0.508 C
Thick-billed murre	0.090 D
Shaak Island	
Mirex	
Tufted puffin	0.006 A
Common murre	ND B
Cis-chlordane[a]	
Tufted puffin	0.008 A
Common murre	ND B
PCB's	
Tufted puffin	0.423 A
Common murre	0.147 B
St. George Island	
DDD	
Common murre	0.035 A
Northern fulmar	0.008 B
Heptachlor epoxide	
Common murre	0.012 A
Northern fulmar	0.005 B
Oxychlordane	
Northern fulmar	0.067 A
Common murre	0.018 B
Cis-chlordane[a]	
Northern fulmar	0.001 A
Common murre	ND B
Cis-nonachlor	
Northern fulmar	0.003 A
Common murre	ND B

Table 8. Continued

Site, compound and species	Geometric mean[a]
St. Paul Island	
DDE	
Common murre	0.135 A
Black-legged kittiwake	0.033 B
Dieldrin	
Common murre	0.005 A
Black-legged kittiwake	<0.001 B
Heptachlor epoxide	
Common murre	0.011 A
Black-legged kittiwake	0.003 B
Oxychlordane	
Black-legged kittiwake	0.034 A
Common murre	0.026 B
HCB	
Common murre	0.080 A
Black-legged kittiwake	0.043 B
PCB's	
Black-legged kittiwake	0.472 A
Common murre	0.205 B
Bluff Seabird Cliffs	
DDE	
Common murre	0.141 A
Black-legged kittiwake	0.033 B
DDD	
Common murre	0.010 A
Black-legged kittiwake	0.001 B
Oxychlordane	
Common murre	0.023 A
Black-legged kittiwake	0.010 B
HCB	
Common murre	0.111 A
Black-legged kittiwake	0.031 B
PCB's	
Black-legged kittiwake	0.365 A
Common murre	0.182 B

[a] For each site, means that do not share the same letter are significantly different ($P < 0.05$) from each other (each compound considered separately).

[b] ND = not detected in these samples.

[c] Or *trans*-nonachlor, or both (see Methods).

[d] Mean reflects collections in two years with significant differences among years; see Appendix III.

Discussion and Conclusions

Although the concentrations were usually low, the eggs from Alaska contained a broader array of organochlorines than has typically been reported in samples from remote locations. This larger number is probably a result of our analyzing the samples at a higher level of sensitivity than that used in most similar studies. Concentrations of DDE are usually higher than the concentrations of other organochlorines in field-collected specimens (Ohlendorf et al. 1978*b*). This was generally also true of our samples from Alaska. However, HCB occurred in most of the eggs we analyzed, and in concentrations that sometimes exceeded those of DDE—particularly at sites in the Pribilof Islands and Seward Peninsula. This widespread occurrence may mean that the primary source of HCB is in the northwestern Pacific, or that HCB is entering the region by way of oceanic gyres. The high concentrations of organochlorines in eggs of all species from Buldir Island and in the glaucous-winged gulls from Bogoslof Island, which are relatively remote sites, probably means that birds nesting on these islands are obtaining these contaminants from sources outside Alaska.

In the following sections we review the literature on occurrence of organochlorines in northern seabirds, and the possible relation of food, migration, and winter distribution to the organochlorine content of their eggs.

Organochlorine Residues in Northern Seabirds

Eggs of several species of marine birds collected in 1970 from the Strait of Georgia, the west coast of Vancouver Island, and the Queen Charlotte Islands of British Columbia were analyzed for residues of organochlorines (Ohlendorf et al. 1978*b*). The ratios of PCB to DDE in those eggs were often similar to ratios in the present samples from Alaska. Eggs of Leach's storm-petrel from Vancouver Island contained somewhat higher concentrations of DDE (about 2.2 ppm, converted from lipid-weight basis) and PCB's (about 1.1 ppm) than did our samples of this species from Buldir Island. In the only two eggs of fork-tailed storm-petrel from the Queen Charlotte Islands that were analyzed, concentrations of DDE (4.1 ppm) and PCB's (15 ppm) were much higher than in eggs from Alaska.

Concentrations of DDE (0.5 and 0.8 ppm) and PCB's (2.6 and 5.4 ppm) in eggs of pelagic cormorant from two locations in the Strait of Georgia (Ohlendorf et al. 1978*b*) were several times higher than those in eggs from Middleton Island and Buldir Island in Alaska. Residue concentrations in eggs of double-crested cormorant were much higher (4.1 ppm DDE; 14 ppm PCB's) than in Alaskan samples.

Organochlorine concentrations in eggs of glaucous-winged gulls from various Strait of Georgia, Vancouver Island, and Queen Charlotte Islands locations (Ohlendorf et al. 1978*b*) were, in general, similar to those in eggs from Alaska. The most frequent difference was that concentrations of PCB's in the eggs from British Columbia were slightly higher than in those from Alaska.

White and Risebrough (1977) analyzed eggs and tissues of several seabird species from Amchitka and Agattu (Aleutian Islands); however, because of variations in the manner of reporting residue concentrations and the small sample sizes, it is difficult to make direct comparisons between our results and theirs. They suggested that local sources of PCB contamination (including the disposal of PCB-containing refuse on beaches) appeared to be a more plausible source of PCB's in Alaskan birds than did atmospheric or oceanic transport of these chemicals from Japan. In a small sample of representative prey species of peregrine falcons (*Falco peregrinus*) from Amchitka, concentrations of DDE in the migrant prey species averaged 2.8 times greater than in resident species sampled (White et al. 1973).

Eggs of eleven species of marine and estuarine birds were collected in Oregon during 1979 (C. J. Henny et al., unpublished data). Seven species showed geometric mean concentrations of DDE that were less than 1 ppm, and mean concentrations of PCB's in eight species were below 1 ppm.

Concentrations of DDE (about 41 ppm, converted from concentrations reported on a lipid-weight basis) and PCB's (about 23 ppm) in eggs of common murre from the Farallon Islands, California (Gress et al. 1971) were about two orders of magnitude higher than in eggs of either species of murre from Alaska. Coulter and Risebrough (1973) reported that eggs of the ashy storm-petrel (*Oceanodroma homochroa*) from that site also contained higher concentrations of DDE (about 62 ppm) and PCB's (about 38 ppm) than did eggs of either species of storm-petrel from Alaska. The Farallon Islands are relatively near local sources of pollution that may have contributed some of the organochlorines found in eggs of these seabirds.

A comparison of DDE and PCB concentrations in eggs of several species of seabirds from Iceland (J. A. Sproul et al., unpublished data) and our samples from Alaska suggests somewhat higher concentrations of residues—especially PCB's—in the Icelandic birds. Concentrations of PCB's in the eggs from Iceland were sometimes an order of magnitude higher than in those from our study, and the ratio of PCB to DDE was often two to four times that in Alaskan eggs of the same or comparable species. In eggs from Iceland, as in our samples from Alaska, the ratio of PCB to DDE was higher in the black-legged kittiwake than in any other species.

Organochlorine concentrations in eggs of Leach's storm-petrel, double-crested cormorant, common murre, and Atlantic puffin (*Fratercula arctica*) collected in eastern Canadian coastal waters in 1970–76 (Pearce et al. 1979) were almost always higher (frequently by at least an order of magnitude) than in the eggs of these or related species we analyzed. However, the ratios of PCB to DDE were similar to those for eggs from Alaska.

Concentrations of DDE and PCB's in eggs of black-legged kittiwake and common murre were considerably higher along the coasts of the British Isles (Parslow 1973) than in Alaska. The ratio of PCB to DDE in murre eggs ranged from 5.0 to 8.9. In kittiwakes the concentration of PCB's was 18 to 50 times that of DDE in the eggs. The mean concentration of PCB's was usually higher in kittiwake than in murre eggs, but DDE concentrations were much higher in murre eggs at all colonies. Parslow (1973) suggested that these differences were related to differences in the birds' feeding ecology and consequently to different levels of exposure to each of these organochlorines. In Britain, murres seemingly feed on small fish in the inshore marine zone throughout the year, whereas kittiwakes feed mainly on macrozooplankton living on or near the surface in offshore and pelagic zones.

Among more than 100 birds collected from the open North Atlantic between Scotland and the Arctic (Bogan and Bourne 1972; Bourne and Bogan 1972), the total organochlorine content in muscle and liver of the auks and the few shearwaters examined was generally low—0.1–1.0 ppm (wet weight?). Concentrations were higher (generally 1–10 ppm) in the more pelagic species, including the black-legged kittiwake, northern fulmar, and British storm-petrel (*Hydrobates pelagicus*). The highest concentrations, often above 10 ppm, were found in large gulls and skuas feeding largely around trawlers in the winter and seabird breeding colonies in the summer. The highest concentrations were found in glaucous gulls (*Larus hyperboreus*) breeding near other seabird colonies, where they apparently fed largely on eggs of other seabirds.

The ratio of PCB to DDE was usually between 2 and 10 to 1 in all species except black-legged kittiwake, in which the ratio was always higher (sometimes at least 60 to 1). This finding suggested to Bogan and Bourne (1972) that kittiwakes have a food source higher in PCB's than the food of the other species, that winter distribution of the species is different, or (less likely) that kittiwakes metabolize or excrete DDE more rapidly than the other species.

The concentration of DDE in five Atlantic puffin eggs collected on St. Kilda (Outer Hebrides, Scotland) in 1969 averaged 0.18 ppm—about one-third the concentration (0.47 ppm) in whole birds (Parslow et al. 1972). PCB's in these eggs apparently did not exceed 0.5 ppm. These concentrations are similar to those we found in eggs of puffins from Alaska.

Residues of DDE and PCB's occurred in each of 203 seabird eggs collected from 10 localities along the coast of Norway by Fimreite et al. (1977). Although some variation in DDE concentrations among sampling sites was noted, there was no south-north gradient. DDE concentrations were highest in herring gull (*Larus argentatus*), lower in common murre and razorbill (*Alca torda*), and lowest in black-legged kittiwake. Within sites and species

PCB concentrations were significantly correlated with those of DDE in practically all groups. The PCB concentrations, however, exceeded the DDE concentrations in all species by a factor that varied from 2.7 in murres to 7.8 for kittiwakes.

Food of Species Samples

Differing food of the species we sampled may account for some of the differences in residue concentrations. Ainley and Sanger (1979) reviewed the literature published through early 1975 on diets of seabirds of the northeastern North Pacific Ocean and Bering Sea, and diets of several species have been studied more recently at certain sites within the region. We briefly summarize here what is known about food in relation to organochlorine contaminants for the principal species in our study. Information is often based on food brought to the chicks before they fledge, but some adults and winter specimens have been collected for study. Most seabirds feed as secondary and tertiary carnivores and eat more than one type of prey (Ainley and Sanger 1979). The major prey species for most seabirds vary by season and location, but there is little information about the diets of seabirds while they are nomadic (Shuntov 1972).

Northern Fulmar and Storm-petrels

The northern fulmar and fork-tailed and Leach's storm-petrels appear to be medium-sized and small surface-feeding generalists (opportunists) that eat whatever they can find (Palmer 1962; Ainley and Sanger 1979). They are principally secondary and tertiary carnivores and scavengers, feeding over outer portions of the continental shelf and in oceanic waters beyond. Typical foods include live and dead fish, squid, coelenterates, crustaceans (especially Euphausiidae), other organisms, and floating oil or blubber from wounded or dead marine mammals. Pearce et al. (1979) suggested that eggs of Leach's storm-petrel from eastern Canada contained high concentrations of organochlorines because petrels feed at the interface of the air and water where these chemicals first reach the oceans and where they may be held on the surface by a thin oily film.

Cormorants

Cormorants are secondary and tertiary carnivores and feed relatively close to shore (Ainley and Sanger 1979). Double-crested cormorants are primarily piscivorous, feeding particularly on schooling fishes that occur at moderate to great depths. Pelagic and red-faced cormorants feed more heavily on benthic fish and decapod crustaceans (see also Palmer 1962 and Hunt 1977).

Glaucous-winged Gull

Glaucous-winged gulls are secondary, tertiary, and upper-level carnivores and scavengers in nearshore habitats (Ainley and Sanger 1979). This species, like other gulls, is an omnivorous opportunist (Trapp 1979). At four locations in the western Aleutian Islands glaucous-winged gulls fed on a large variety of organisms, but at any given site they specialized on the species that were most abundant and vulnerable. Inter-island differences in diet seemed related to island physiography, the available food source, and the effects of sea otters (*Enhydra lutris*) on the structure of the nearshore community. At Alaid-Nizki and Agattu, glaucous-winged gulls fed primarily on intertidal invertebrates; at Buldir and Semisopochnoi the principal food was birds; and at Little Kiska the primary prey was fish. Glaucous-winged gulls have also been observed eating the eggs and young of murres at Bogoslof Island (Gabrielson and Lincoln 1959; Murie 1959; G. V. Byrd, personal communication cited in Trapp 1979). (However, at certain times they feed heavily on walleye pollock [*Theragra chalcogramma*] at Bogoslof Island, as observed by G. J. Divoky and G. V. Byrd [unpublished data].) These locality differences – particularly the high proportion of birds in the diet of gulls at Buldir and Bogoslof islands – may account for the higher concentrations of organochlorine residues in gull eggs from those sites.

Moe and Day (1979) reported that in the Shumagin Islands, birds (or their eggs) and marine invertebrates (mainly intertidal) were the predominant items in food pellets regurgitated by glaucous-winged gulls. These authors believed that fish might have been under-represented in the pellets because they were more readily digested and therefore not cast in pellets.

At Kodiak Island, glaucous-winged gulls ate a greater variety of prey than did black-legged kittiwakes or tufted puffins (Baird and Hatch 1979). Capelin (*Mallotus villosus*) and Pacific sand lance (*Ammodytes hexapterus*) were predominant prey species, and their relative abundance in the area apparently was reflected in the diet. At Ugaiushak Island, glaucous-winged gulls fed primarily on sand lance in July and August in 1977 (Wehle 1978).

Black-legged Kittiwake

Black-legged kittiwakes evidently feed opportunistically, but become specialists if suitable prey is abundant (Drury 1978). Kittiwakes feed at or near the surface; their food varies among the regions of Alaska where studies have been conducted.

In the northwestern Gulf of Alaska, kittiwakes are primarily piscivorous. At Kodiak Island they feed heavily on capelin early in the summer, but sand lance replace capelin as the principal food before the young have fledged (Baird and Moe 1978; Sanger et al. 1978*a*, 1978*b*; Baird and Hatch 1979; Krasnow et al. 1979). Euphausiid crustaceans (especially *Thysanoessa inermis*) are important prey early in the nesting seasons. At Middleton Island, fish (predominantly sand lance) composed almost 80% of the diet in 1978 (Hatch et al. 1979); euphausiids made up most of the rest of it. Kittiwakes nesting in lower Cook Inlet in 1978 fed their chicks almost exclusively fish (Jones and Petersen 1979). Sand lance was the predominant prey species and capelin was secondary in importance.

Kittiwakes in the southern Bering Sea have a varied diet and do not feed heavily on any single species. In the northern Bering Sea and Chukchi Sea, birds of different colonies eat different foods, but capelin is not usually an important prey species (Hunt 1977; Biderman et al. 1978; Divoky 1978; Drury 1978; Springer and Roseneau 1978; Ramsdell and Drury 1979; Springer et al. 1979). For some colonies, sand lance become an important food source in early August while the young are still in the nest. In the northern Chukchi Sea and in Beaufort Sea, kittiwakes eat primarily arctic cod, *Boreogadus saida* (G. J. Divoky, unpublished data).

Kittiwakes wintering in Monterey Bay, California, and which probably breed in Alaska, feed heavily on squid (*Loligo opalescens*) during the winter, but they also eat anchovies (*Engraulis mordax*) and euphausiid crustaceans (Morejohn et al. 1978).

We found no apparent dietary differences in kittiwakes (compared with the other species we studied) that would account for the much higher PCB to DDE ratio we have reported. (As we noted previously, kittiwakes have low concentrations of DDE, rather than high concentrations of PCB's, that cause the ratio to be higher than in other species.) Perhaps physiological differences or other factors, such as concentrations of organochlorines in their winter prey, may be involved.

Murres and Puffins

Murres and puffins feed heavily on fish, mainly species that school in midwater (Ainley and Sanger 1979). Like many other species, these birds are opportunistic, feeding rather heavily at times on cephalopods and crustaceans, particularly nektonic forms. Morphological differences between the two murre species suggest that thick-billed murres feed on benthic organisms much more than do common murres, and that the common murre is the more piscivorous (Bedard 1969; Spring 1971; see also Hunt 1977 and Springer and Roseneau 1978). However, when the two murres feed together along the Bering Sea ice "front," their diets are similar (Divoky 1978); both then feed primarily on walleye pollock, capelin, hyperiid amphipods (*Parathemisto libellula*), and euphausiid crustaceans that are among the more abundant potential prey available in the area.

In the Kodiak Island area and on Ugaiushak Island, common murres were exclusively piscivorous and tufted puffins were largely so during the summer of 1977 (Sanger et al. 1978*b*; Wehle 1978). Capelin was the most important prey species; euphausiid crustaceans and squid were taken seasonally. The following year both species fed largely on fish in the Kodiak area; capelin and sand lance were the principal forage fishes for each species (Krasnow et al. 1979). Common murres also fed extensively on walleye pollock; fish made up 98% of the diet.

Common murres in Kachemak Bay, Alaska, fed much less extensively on fish (from November 1977 to April 1978) than they did in the Kodiak area or at other sites where their food has been studied (Sanger and Jones 1981). Crustaceans made up 84% of the diet in the Bay; shrimp (Pandalidae) and mysids (*Neomysis rayii*) were the most important prey. In marked contrast, fish were the most important prey at other locations. However, these findings may reflect seasonal differences in diet: in summer, murres are almost exclusively piscivorous in the Kodiak area (Sanger et al. 1978*b*; Krasnow et al. 1979) and in the Bering Sea (Hunt 1976; Ogi and Tsujita 1973).

Thick-billed murres in the northern North Pacific Ocean feed primarily on squid and euphausiids (Ogi 1978). Squid are the most important prey, and fish are less important than invertebrates.

Tufted puffins feed primarily on capelin and sand lance in the Kodiak area during summer (Baird and Moe 1978; Moe and Baird 1978; Baird and Hatch 1979). Capelin was the most important prey species in 1977 but the puffins ate more sand lance in 1978, apparently because capelin were less abundant. Other species of fish made up most of the rest of the diet, but some cephalopods (less than 5% of the diet) and euphausiids were eaten.

Although tufted puffins at Middleton Island in 1978 ate principally sand lance, they also fed extensively on squid and octopus, which made up 36% of the diet (Hatch et al. 1979). These cephalopods were probably obtained in deepwater foraging areas beyond the continental slope, some 15 to 25 km from the nesting area.

In 1978, horned puffins nesting in lower Cook Inlet apparently fed their chicks only sand lance (Jones and Petersen 1979). Sand lance also was the predominant food for horned puffin chicks in the Shumagin Islands in 1976, constituting 70% of the diet; capelin made up 20% (Moe and Day 1979). The relative importance of these two species shifted during the two and one-half week sampling period in August; consumption of sand lance increased and that of capelin decreased.

Both tufted and horned puffins on Buldir Island during the summer of 1975 fed primarily on squid and sand lance (D. H. S. Wehle, personal communication). In the Barren Islands they both feed primarily on capelin and sand lance (Amaral and Manuwal 1978; Manuwal and Boersma 1978); several other fish species compose most of the rest of the diet.

Although the diets of murres (especially common murres) and puffins consist primarily of fish, the specific prey species and their relative importance in the diet change seasonally and geographically. Murres and puffins also eat invertebrates in large numbers when they are available. However, the diets of these birds are not known in sufficient detail to enable us to determine whether they might account for differences we found in organochlorine residue content in their eggs.

Migration and Winter Distribution

Species differences in winter distribution and migration patterns may account for differences in residue concentrations. There are insufficient data to accurately describe the migrations of most marine birds in Alaska (Gill et al. 1979), but an attempt is made here to summarize the available information. The habits of intensively hunted and managed species and populations of waterfowl are somewhat better known, but the migrations of most alcids and cliff-nesters are poorly known, primarily because of their tendency to disperse randomly from colony areas after breeding. There are few recoveries of seabirds banded in Alaska for any of the species we studied. For each species except the glaucous-winged gull, there are fewer than five recoveries, and even for the gull fewer than 200 recoveries had been reported to the U.S. Fish and Wildlife Service Bird Banding Laboratory by September 1980.

Northern Fulmar

Most northern fulmars apparently overwinter within several hundred kilometers of their nesting colonies, but move away from shore into the open oceans (Dement'ev et al. 1951*c*; Shuntov 1972). Some, however – perhaps mostly juveniles and unmated adults – wander far north and south, year round. The winter range of the northern Pacific Ocean breeding population extends from the Aleutian Islands southward to Japan and Baja California (Dement'ev et al. 1951*c*; Gabrielson and Lincoln 1959; Palmer 1962; Shuntov 1972).

Storm-petrels

Fork-tailed storm-petrels disperse far north and south from their nesting sites (Palmer 1962). Through the winter they remain relatively near coastal areas from Japan to the edge of frozen seas in the vicinity of the Bering Strait, throughout the Aleutian Islands, and southward along the North American coast to California (Dement'ev et al. 1951*c*; Gabrielson and Lincoln 1959; Palmer 1962). The winter distribution of Leach's storm-petrels in the Pacific Ocean is not well known, but the birds presumably occur in the open ocean near their nesting grounds (Gabrielson and Lincoln 1959) or concentrate along tropical convergences from Japan to Baja California (Dement'ev et al. 1951*c*; Palmer 1962).

Cormorants

Migratory movements for all species of cormorants are poorly known, for they are among the first to arrive at breeding cliffs and among the last to depart (Gill et al. 1979). Northern breeding populations of the pelagic cormorant are migratory and southern populations are resident (Dement'ev et al. 1951*a*; Gabrielson and Lincoln 1959; Palmer 1962; Gill et al. 1979). Wintering areas include the Pribilof and Aleutian islands and North Pacific coastal waters.

Both spring and fall movements are more restricted for the red-faced cormorant, which is resident throughout most of its breeding range (Dement'ev et al. 1951*a*; Gabrielson and Lincoln 1959; Gill et al. 1979). However, observers have much difficulty in distinguishing between red-faced and pelagic cormorants in winter plumage, and large numbers of red-faced cormorants may migrate to North Pacific coastal waters where they are mixed with pelagic cormorants (Gill et al. 1979).

Glaucous-winged Gull

Glaucous-winged gulls spend the winter from the area of Kamchatka eastward throughout the Aleutian Islands, the Gulf of Alaska, and southward along the coast to southern Baja California, the Gulf of California, and Sonora (Dement'ev et al. 1951*b*; Gabrielson and Lincoln 1959). The birds are year-round residents in most of the breeding range, withdrawing largely from the more northern areas in winter but wintering regularly throughout the Aleutians and the Pribilofs and abundantly farther south.

As judged by recoveries of birds banded in Alaska, some glaucous-winged gulls from the western Aleutian Islands migrate to the vicinity of Kamchatka and southward to Japan. Along the North American coast, most winter recoveries are from British Columbia. Some recoveries of birds banded in Alaska have been reported from California, but none from areas farther south.

Black-legged Kittiwake

Pacific populations of the black-legged kittiwake breed along coastal cliffs of Siberia and Alaska and wander about the open ocean in two major wintering areas: (1) south of the Aleutian Islands and east of Japan, and (2) along the coast from British Columbia to Baja California (Dement'ev et al. 1951*b*; Gabrielson and Lincoln 1959; Shuntov 1972; Gill et al. 1979). Few kittiwakes winter in the Gulf of Alaska or in the southern Bering Sea (Kenyon 1949; Shuntov 1972). However, it is still unknown where specific breeding populations winter (Gill et al. 1979). For the eastern Bering Sea population there is a broad and gradual movement from breeding colonies to wintering areas south of the Aleutians, whereas populations from the Gulf of Alaska are believed to have a more narrowly channeled movement along the continental shelf on the east side of the Pacific to their wintering areas south of British Columbia.

Murres

There is no evidence of regular migratory movements by common murres or thick-billed murres, except in the northern part of the range (Gabrielson and Lincoln 1959). Apparently, only breeding populations in the Chukchi and northern Bering seas have well defined migration routes to and from the breeding grounds (Gill et al. 1979). The more southerly populations, especially those breeding in the Gulf of Alaska and in the Bering Sea south of winter ice advance, are believed to move randomly from colonies and assume a pelagic existence in winter, usually over the continental shelf, with some birds moving into the protected waters of southern Alaska (Gabrielson and Lincoln 1959). In the southern Bering Sea, winter populations associated with the ice edge have been described as having the greatest densities of any throughout the murres' winter range (Shuntov 1972; Divoky 1977), and are probably composed chiefly of birds breeding throughout the Bering Sea. However, a substantial population of Bering Sea breeders do not winter in the area but migrate through Unimak Pass into the Gulf of Alaska each fall (Gill et al. 1979).

Tufted Puffin

The tufted puffin, like most alcids, has no well-defined migration (Gill et al. 1979). Instead, it disperses over the open ocean, usually off the continental shelf in the southern Bering Sea and oceanic areas south of Alaska, after breeding (Dement'ev et al. 1951*c*; Shuntov 1972; Sowls et al. 1978; Gill et al. 1979). The species is resident except in the areas north of the Aleutians, from which it withdraws to the south (Gabrielson and Lincoln 1959).

Summary

Records indicate on a broad scale that Alaskan waters, and its marine fauna, are evidently contaminated with organochlorine pollutants. However, more specific information concerning migration, food, and physiology of these species and the occurrence of organochlorines in food organisms is needed to indicate pollution relationships for local areas. The widespread occurrence of DDE and PCB's in the environment, including remote areas of the arctic and antarctic, has been documented previously. In addition to those compounds, we found a broad array of other organochlorines in eggs of Alaskan seabirds. This finding indicates that Alaskan seabirds are exposed to these chemicals, probably through their food, and that the chemicals are probably not uniformly distributed in the areas we sampled or in those used by these seabirds in winter.

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Appendix I

Collectors of Alaskan Seabird Eggs, 1973–76

Site	Collector
Copper River Delta	S. M. Patten
Hinchinbrook Island	P. M. Knudtson D. R. Nysewander
Middleton Island	D. A. Frazer
Barren Islands	D.A. Manuwal
Amalik Bay	G. J. Divoky
Kodiak Island	M. H. Dick J. Nelson G. A. Sanger
Ugaiushak Island	E. P. Hoberg D. H. S. Wehle
Semidi Islands	G. C. Burrell S. A. Hatch L. L. Leschner
Shumagin Islands	R. H. Day R. A. Moe
Bogoslof Island	G. J. Divoky
Buldir Island	G. V. Byrd D. H. S. Wehle
Attu Island	E. P. Hoberg
Round Island	J. C. Bartonek
Shaiak Island	J. C. Bartonek G. J. Divoky
St. George Island	J. J. Hickey
St. Paul Island	G. L. Hunt, Jr. M. W. Hunt
Bluff Seabird Cliffs	W. H. Drury
King Island	W. H. Drury

Appendix II

Chemical Names of Compounds Mentioned in the Text

Cis-chlordane	1-exo,2-exo,4,5,6,7,8,8-octachloro-2,3,3a,4,7,7a-hexahydro-4,7-methanoindene
Cis-nonachlor	1-exo,2-exo,3-exo,4,5,6,7,8,8-nonachloro-2,3,3a,4,7,7a-hexahydro-4,7-methanoindene
p,p'-DDD	1,1-dichloro-2,2-bis(p-chlorophenyl)ethane
p,p'-DDE	1,1-dichloro-2,2-bis(p-chlorophenyl)ethylene
p,p'-DDT	1,1,1-trichloro-2,2-bis(p-chlorophenyl)ethane
Dieldrin	1,2,3,4,10,10-hexachloro-6,7-epoxy-1,4,4a,5,6,7,8,8a-octahydro-1,4-endo-exo-5,8-dimethanonaphthalene
Endrin	1,2,3,4,10,10-hexachloro-6,7-epoxy-1,4,4a,5,6,7,8,8a-octahydro-1,4-endo-endo-5,8-dimethanonaphthalene
HCB	hexachlorobenzene
Heptachlor epoxide	1,4,5,6,7,8,8-heptachloro-6,7-epoxy-3a,4,7,7a-tetrahydro-4,7-methanoindane
Mirex	dodecachlorooctahydro-1,3,4-metheno-1H-cyclobuta [cd]pentalene
Oxychlordane	1-exo,2-endo,4,5,6,7,8,8-octachloro-2,3-epoxy-2,3,3a,4,7,7a-hexahydro-4,7-methanoindene
PCB (polychlorinated biphenyls)	Mixtures of chlorinated biphenyl compounds having various percentages of chlorine.
Toxaphene	Chlorinated camphene (content of combined chlorine, 67-69%)
Trans-nonachlor	1-exo,2-endo,3-exo,4,5,6,7,8,8-nonachloro-2,3,3a,4,7,7a-hexahydro-4,7-methanoindene

Appendix III

Organochlorine Residue Concentrations (geometric mean, 95% confidence interval [CI], and range) in Eggs of Alaskan Seabirds, by Species, 1973–76

Lipid content of the eggs is given as mean and SE. The lipid percentages reported here may not represent the normal content of fresh eggs, because some eggs contained embryos at various stages of development and minor decomposition may have occurred in some eggs. *Cis*-chlordane was not separable from *trans*-nonachlor in 1973–75; residues of these chemicals in samples from 1976 were combined to facilitate presentation of data (see Methods). Chemicals not listed for a particular locality were not detected in eggs of that species from that locality; ND = not detected.

		Residues in ppm (wet weight)		
Region; site; N, year, and PCB/DDE; and chemical	No. with residues	Mean	95% CI	Range
A. Common loon (N = 1; lipid content = 5.20%)				
Gulf of Alaska				
Kodiak Island				
N = 1; 1975; 2.0				
DDE	1	0.550	—	—
DDD	1	0.012	—	—
DDT	1	0.015	—	—
Dieldrin	1	0.023	—	—
Heptachlor epoxide	1	0.013	—	—
Mirex	1	0.009	—	—
Oxychlordane	1	0.015	—	—
Cis-chlordane	1	0.065	—	—
Cis-nonachlor	1	0.009	—	—
HCB	1	0.021	—	—
Toxaphene	1	0.120	—	—
PCB's	1	1.10	—	—
B. Northern fulmar (N = 22; lipid content = 7.67 ± 0.33%)				
Gulf of Alaska				
Semidi Islands				
N = 16; 1976; 1.0				
DDE	16	0.484	0.26-0.75	0.19-2.8
DDD	12	0.007	0.004-0.010	ND-0.019
DDT	16	0.048	0.032-0.065	0.005-0.13
Dieldrin	8	0.005	0.002-0.007	ND-0.016
Heptachlor epoxide	1	<0.001	0-0.0007	ND-0.004
Mirex	9	0.004	0.002-0.006	ND-0.010
Oxychlordane	16	0.033	0.026-0.041	0.015-0.063
HCB	11	0.008	0.005-0.011	ND-0.018
PCB's	16	0.484	0.36-0.62	0.20-1.2
Pribilof Islands				
St. George Island				
N = 6; 1975; 1.3				
DDE	6	0.307	0.19-0.44	0.14-0.45
DDD	5	0.008	0.002-0.013	ND-0.015
DDT	6	0.015	0.001-0.029	0.006-0.041
Dieldrin	5	0.008	0.003-0.013	ND-0.015
Heptachlor epoxide	3	0.005	0-0.011	ND-0.013
Mirex	2	0.002	0-0.006	ND-0.008
Oxychlordane	6	0.067	0.021-0.12	0.007-0.14
Cis-chlordane	2	0.001	0-0.004	ND-0.005
Cis-nonachlor	2	0.003	0-0.007	ND-0.008
HCB	6	0.055	0.033-0.077	0.028-0.089
Toxaphene	6	0.051	0.028-0.074	0.029-0.081
PCB's	6	0.387	0.19-0.61	0.26-0.81

Appendix III. Continued

		Residues in ppm (wet weight)		
Region; site; N, year, and PCB DDE; and chemical	No. with residues	Mean	95% CI	Range
C. Fork-tailed storm-petrel (N = 11; lipid content = 7.17 ± 0.37%)				
Gulf of Alaska				
Barren Islands				
N = 4; 1976; 2.2				
DDE	4	0.700	0.40-1.1	0.48-0.89
DDD	4	0.155	0.12-0.19	0.14-0.19
DDT	4	0.072	0-0.16	0.018-0.15
Dieldrin	4	0.020	0.004-0.036	0.010-0.029
Heptachlor epoxide	2	0.007	0-0.020	ND-0.016
Mirex	3	0.044	0-0.12	ND-0.11
Oxychlordane	4	0.084	0.077-0.091	0.079-0.090
Cis-chlordane	4	0.049	0.015-0.085	0.021-0.068
Cis-nonachlor	3	0.012	0-0.029	ND-0.025
HCB	4	0.020	0-0.042	0.005-0.036
PCB's	4	1.51	1.1-2.0	1.2-1.9
Aleutian Islands				
Buldir Island				
N = 7; 1975; 2.8				
DDE	7	0.602	0.51-0.70	0.43-0.70
DDD	5	0.157	0.043-0.28	ND-0.28
DDT	6	0.140	0.040-0.25	ND-0.31
Dieldrin	4	0.032	0-0.073	ND-0.099
Heptachlor epoxide	2	0.001	0-0.003	ND-0.004
Mirex	7	0.026	0.014-0.039	0.003-0.044
Oxychlordane	7	0.059	0.036-0.082	0.021-0.098
Cis-chlordane	7	0.053	0.038-0.068	0.026-0.072
Cis-nonachlor	4	0.004	0-0.009	ND-0.013
HCB	7	0.041	0.036-0.045	0.034-0.047
Toxaphene	7	0.101	0.040-0.17	0.039-0.25
PCB's	7	1.69	1.4-2.1	1.2-2.3
D. Leach's storm-petrel (N = 11; lipid content = 9.54 ± 0.38%)				
Aleutian Islands				
Buldir Island				
N = 11; 1974; 1.5				
DDE	11	0.337	0.23-0.45	0.14-0.74
DDD	7	0.017	0.005-0.028	ND-0.052
DDT	7	0.019	0.006-0.032	ND-0.052
Dieldrin	3	0.002	0-0.005	ND-0.010
Heptachlor epoxide	1	<0.001	0-0.002	ND-0.006
Oxychlordane	7	0.016	0-0.037	ND-0.11
Cis-chlordane	7	0.006	0.003-0.009	ND-0.012
Cis-nonachlor	10	0.013	0.008-0.017	ND-0.024
HCB	11	0.018	0.011-0.024	0.009-0.042
Toxaphene	11	0.050	0.033-0.066	0.024-0.11
PCB's	11	0.508	0.36-0.68	0.19-1.1
E. Double-crested cormorant (N = 7; lipid content = 1.94 ± 0.34%)				
Gulf of Alaska				
Ugaiushak Island				
N = 4; 1974; 1.4				
DDE	4	0.080	0.073-0.088	0.074-0.085
Heptachlor epoxide	2	0.006	0-0.017	ND-0.013
Oxychlordane	2	0.007	0-0.019	ND-0.014
HCB	4	0.013	0.011-0.015	0.011-0.014
PCB's	4	0.111	0.042-0.18	0.064-0.17

Appendix III. Continued

		Residues in ppm (wet weight)		
Region; site; N, year, and PCB DDE; and chemical	No. with residues	Mean	95% CI	Range
Bristol Bay				
Shaiak Island				
N = 3; 1973; 1.0				
DDE	3	0.394	0-1.2	0.13-0.63
DDD	1	0.001	0-0.008	ND-0.004
Dieldrin	3	0.037	0-0.085	0.026-0.059
Heptachlor epoxide	2	0.005	0-0.015	ND-0.008
Oxychlordane	2	0.004	0-0.015	ND-0.008
Cis-nonachlor	3	0.009	0.002-0.016	0.007-0.012
HCB	3	0.040	0-0.15	0.004-0.084
PCB's	3	0.400	0.12-0.75	0.28-0.53
F. Pelagic cormorant (N = 13; lipid content = 3.05 ± 0.20%)				
Gulf of Alaska				
Middleton Island				
N = 11; 1976; 2.2				
DDE	11	0.134	0.092-0.18	0.037-0.24
DDD	4	0.003	0-0.006	ND-0.010
DDT	9	0.005	0.003-0.007	ND-0.008
Dieldrin	11	0.020	0.016-0.024	0.014-0.035
Heptachlor epoxide	11	0.007	0.006-0.008	0.005-0.009
Oxychlordane	11	0.009	0.008-0.010	0.006-0.011
Cis-chlordane	11	0.032	0.026-0.038	0.018-0.050
Cis-nonachlor	7	0.005	0.002-0.008	ND-0.010
HCB	1	0.011	0-0.37	ND-0.13
Toxaphene	10	0.081	0.020-0.14	ND-0.35
PCB's	11	0.296	0.18-0.42	0.082-0.74
Aleutian Islands				
Buldir Island				
N = 2; 1974; 1.4				
DDE	2	0.178	0-1.5	0.11-0.25
DDT	1	0.002	0-0.032	ND-0.005
Heptachlor epoxide	1	0.003	0-0.045	ND-0.006
Cis-chlordane	2	0.021	0-0.087	0.016-0.026
HCB	2	0.015	0-0.088	0.010-0.021
Toxaphene	2	0.012	0-0.025	0.011-0.013
PCB's	2	0.254	0-6.3	0.092-0.44
G. Red-faced cormorant (N = 1; lipid content = 2.7%)				
Gulf of Alaska				
Ugaiushak Island				
N = 1; 1974; 2.9				
DDE	1	0.042		
Cis-chlordane	1	0.021		
Cis-nonachlor	1	0.006		
Toxaphene	1	0.021		
PCB's	1	0.120		
H. Aleutian Canada goose (N = 1; lipid content = 13.0%)				
Aleutian Islands				
Buldir Island				
N = 1; 1974; 0.1				
DDE	1	0.045		
Dieldrin	1	0.011		
Heptachlor epoxide	1	0.005		
PCB's	1	0.006		

Appendix III. Continued

		Residues in ppm (wet weight)		
Region; site: N, year, and PCB/DDE; and chemical	No. with residues	Mean	95% CI	Range
J. Glaucous-winged gull (N = 123; lipid content = 5.78 ± 0.11%)				
Gulf of Alaska				
Copper River Delta				
N = 36; 1976; 1.7				
DDE	36	0.116	0.086-0.15	0.005-0.46
DDD	11	0.003	0.001-0.005	ND-0.017
DDT	1	<0.001	0-0.002	ND-0.02
Dieldrin	20	0.005	0.003-0.008	ND-0.043
Heptachlor epoxide	12	0.003	0.001-0.005	ND-0.022
Mirex	4	<0.001	0-0.002	ND-0.016
Oxychlordane	17	0.007	0.004-0.010	ND-0.034
Cis-chlordane	8	0.003	0-0.006	ND-0.045
Cis-nonachlor	5	0.001	0-0.002	ND-0.009
HCB	35	0.015	0.011-0.020	ND-0.089
PCB's	31	0.194	0.12-0.28	ND-1.5
Hinchinbrook Island				
N = 10; 1976; 1.7				
DDE	10	0.277	0.13-0.45	0.083-0.73
DDD	9	0.007	0.005-0.009	ND-0.011
Dieldrin	9	0.009	0.005-0.013	ND-0.021
Heptachlor epoxide	10	0.014	0.007-0.022	0.003-0.041
Oxychlordane	10	0.014	0.010-0.017	0.005-0.020
Cis-chlordane	9	0.011	0.007-0.015	ND-0.02
Cis-nonachlor	2	0.001	0-0.003	ND-0.006
HCB	8	0.019	0.009-0.028	ND-0.038
Toxaphene	6	0.010	0.004-0.017	ND-0.022
PCB's	10	0.461	0.32-0.61	0.16-0.84
Middleton Island				
N = 10; 1976; 1.7				
DDE	10	0.540	0.33-0.78	0.19-1.0
DDD	6	0.005	0.001-0.009	ND-0.014
DDT	4	0.004	0-0.009	ND-0.022
Dieldrin	10	0.021	0.015-0.028	0.012-0.043
Heptachlor epoxide	9	0.010	0.003-0.016	ND-0.034
Oxychlordane	10	0.020	0.010-0.029	0.007-0.055
Cis-chlordane	8	0.012	0.004-0.020	ND-0.041
Cis-nonachlor	1	<0.001	0-0.003	ND-0.008
Toxaphene	4	0.007	0-0.014	ND-0.028
PCB's	10	0.941	0.60-1.4	0.37-2.1
Barren Islands				
N = 2; 1976; 1.7				
DDE	2	0.348	0-3.8	0.22-0.49
DDD	1	0.002	0-0.031	ND-0.004
Dieldrin	2	0.033	0-0.38	0.009-0.057
Heptachlor epoxide	2	0.031	0-0.41	0.006-0.056
Mirex	1	0.003	0-0.043	ND-0.006
Oxychlordane	2	0.019	0-0.19	0.007-0.032
Cis-chlordane	1	0.005	0-0.071	ND-0.010
HCB	2	0.027	0-0.13	0.019-0.035
PCB's	2	0.580	0-7.9	0.38-0.81
Amalik Bay				
N = 5; 1973; 1.1				
DDE	5	0.334	0.083-0.64	0.043-0.66
DDT	1	0.001	0-0.005	ND-0.006
Dieldrin	5	0.025	0.008-0.042	0.010-0.046

Appendix III. Conti.

Region; site; N, year, and PCB/DDE; and chemical	No. with residues	Residues in ppm (wet weight)		
		Mean	95% CI	Range
Heptachlor epoxide	3	0.007	0-0.018	ND-0.021
Oxychlordane	4	0.008	0.002-0.015	ND-0.014
Cis-chlordane	1	0.001	0-0.005	ND-0.007
Cis-nonachlor	1	0.002	0-0.007	ND-0.010
HCB	4	0.028	0.006-0.051	ND-0.044
PCB's	5	0.377	0.16-0.64	0.088-0.52
Kodiak Island				
N = 11, 1975; 6, 1976; 1.8				
DDE	17	0.661	0.37-1.0	0.12-2.7
DDD	8	0.007	0.001-0.012	ND-0.036
DDT	9	0.011	0.001-0.020	ND-0.072
Dieldrin—1975	11	0.034	0.019-0.049	0.008-0.069
—1976	4	0.009	0-0.018	ND-0.024
Heptachlor epoxide	15	0.025	0.015-0.036	ND-0.072
Mirex	1	0.002	0-0.006	ND-0.033
Oxychlordane	17	0.024	0.015-0.032	0.007-0.066
Cis-chlordane	11	0.013	0.006-0.020	ND-0.050
Cis-nonachlor	4	0.004	0-0.008	ND-0.033
HCB	10	0.011	0.005-0.017	ND-0.035
Toxaphene—1975	9	0.012	0.006-0.018	ND-0.026
1976	0			—
PCB's	17	1.22	0.75-1.8	0.14-4.4
Ugamshak Island				
N = 3, 1974; 10, 1976; 2.0				
DDE	13	0.298	0.16-0.45	0.038-0.84
DDD	7	0.005	0.002-0.008	ND-0.016
DDT	3	0.003	0-0.008	ND-0.028
Dieldrin	12	0.009	0.006-0.011	ND-0.017
Heptachlor epoxide	11	0.010	0.004-0.016	ND-0.033
Mirex	2	0.002	0-0.005	ND-0.016
Oxychlordane	11	0.021	0.008-0.035	ND-0.077
Cis-chlordane	8	0.010	0.004-0.017	ND-0.030
Cis-nonachlor	5	0.004	0-0.008	ND-0.021
HCB	13	0.031	0.020-0.041	0.007-0.079
Toxaphene	1	0.004	0-0.014	ND-0.057
PCB's	13	0.609	0.31-0.97	0.054-2.0
Semidi Islands				
N = 10, 1976; 1.3				
DDE	10	0.559	0.40-0.74	0.26-0.96
DDD	7	0.010	0.001-0.018	ND-0.040
DDT	6	0.013	0.002-0.025	ND-0.044
Dieldrin	8	0.012	0.004-0.021	ND-0.036
Heptachlor epoxide	10	0.011	0.007-0.015	0.004-0.022
Mirex	7	0.036	0-0.086	ND-0.22
Oxychlordane	10	0.031	0.020-0.042	0.018-0.065
Cis-chlordane	10	0.017	0.006-0.029	0.006-0.046
Cis-nonachlor	5	0.026	0-0.072	ND-0.22
HCB	10	0.040	0.027-0.054	0.018-0.073
PCB's	10	0.741	0.51-1.0	0.36-1.8
Shumagin Islands				
N = 10, 1976; 2.2				
DDE	10	0.284	0.20-0.38	0.11-0.46
DDD	3	0.002	0-0.005	ND-0.009
DDT	3	0.006	0-0.015	ND-0.041

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Appendix III. Continued

Region; site; N, year, and PCB/DDE; and chemical	No. with residues	Residues in ppm (wet weight) Mean	95% CI	Range
Dieldrin	9	0.017	0.009-0.025	ND-0.039
Heptachlor epoxide	5	0.005	0.001-0.009	ND-0.013
Mirex	4	0.025	0-0.050	ND-0.096
Oxychlordane	8	0.031	0.006-0.057	ND-0.13
Cis-chlordane	4	0.006	0-0.013	ND-0.030
HCB	10	0.054	0.039-0.069	0.019-0.085
Toxaphene	1	0.013	0-0.044	ND-0.14
PCB's	10	0.613	0.44-0.80	0.27-1.0
Aleutian Islands				
Bogoslof Island				
N = 3; 1973; 0.7				
DDE	3	5.16	0-42.0	1.6-11.0
DDT	2	0.037	0-0.13	ND-0.073
Dieldrin	3	0.214	0-1.1	0.049-0.58
Mirex	3	0.036	0.013-0.59	0.025-0.042
Oxychlordane	3	0.251	0-1.1	0.054-0.56
HCB	3	0.058	0-0.12	0.030-0.073
PCB's	3	3.55	0.38-14.0	1.8-6.3
Buldir Island				
N = 4; 1975; 1.5				
DDE	4	2.27	0-26.0	0.37-22.0
DDD	3	0.037	0-0.088	ND-0.074
DDT	2	0.022	0-0.066	ND-0.056
Dieldrin	1	0.123	0-0.62	ND-0.59
Heptachlor epoxide	3	0.037	0-0.14	ND-0.13
Mirex	4	0.024	0-0.069	0.005-0.065
Oxychlordane	4	0.106	0-0.43	0.014-0.41
Cis-chlordane	4	0.075	0-0.27	0.016-0.26
Cis-nonachlor	1	0.001	0-0.005	ND-0.005
HCB	4	0.188	0-0.89	0.024-0.84
PCB's	4	3.30	0-25.0	0.87-20.0
Bristol Bay				
Shaiak Island				
N = 3; 1973; 2.1				
DDE	3	0.276	0-1.2	0.015-0.54
DDT	1	0.002	0-0.010	ND-0.006
Dieldrin	3	0.033	0-0.084	0.016-0.055
Heptachlor epoxide	3	0.015	0-0.048	0.005-0.030
Mirex	3	0.006	0.001-0.011	0.004-0.008
Oxychlordane	3	0.020	0-0.051	0.007-0.031
Cis-chlordane	2	0.005	0-0.017	ND-0.009
Cis-nonachlor	3	0.011	0-0.027	0.006-0.018
HCB	2	0.036	0-0.13	ND-0.075
PCB's	3	0.586	0-3.0	0.17-1.4
K. Mew gull (N = 5; lipid content = 7.01 ± 0.36%)				
Gulf of Alaska				
Kodiak Island				
N = 5; 1976; 5.1				
DDE	5	0.660	0-2.0	0.10-2.5
DDD	4	0.014	0-0.035	ND-0.043
DDT	3	0.005	0-0.011	ND-0.012
Dieldrin	5	0.025	0.015-0.036	0.013-0.033
Heptachlor epoxide	5	0.010	0.006-0.014	0.007-0.016
Oxychlordane	5	0.033	0.020-0.046	0.017-0.045

Appendix III. Continued

		Residues in ppm (wet weight)		
Region; site; N, year, and PCB/DDE; and chemical	No. with residues	Mean	95% CI	Range
Cis-chlordane	2	0.006	0-0.018	ND-0.023
Cis-nonachlor	2	0.003	0-0.011	ND-0.013
PCB's	5	3.34	2.3-4.7	2.2-4.5
L. Black-legged kittiwake (N = 62; lipid content = 6.02 ± 0.16%)				
Gulf of Alaska				
Hinchinbrook Island				
N = 10; 1976; 4.0				
DDE	10	0.074	0-0.16	0.006-0.47
DDD	2	0.004	0-0.012	ND-0.033
DDT	1	0.002	0-0.006	ND-0.019
Dieldrin	4	0.003	0-0.006	ND-0.012
Heptachlor epoxide	6	0.003	0.008-0.005	ND-0.007
Mirex	4	0.002	0-0.004	ND-0.006
Oxychlordane	10	0.009	0.005-0.014	0.001-0.021
Cis-chlordane	3	0.001	0-0.003	ND-0.006
Cis-nonachlor	1	<0.001	0-0.001	ND-0.002
HCB	10	0.018	0.013-0.024	0.006-0.029
PCB's	10	0.296	0.18-0.42	0.063-0.71
Middleton Island				
N = 10; 1976; 11.5				
DDE	10	0.047	0.034-0.060	0.025-0.086
DDD	1	<0.001	0-0.002	ND-0.006
Dieldrin	1	0.001	0-0.003	ND-0.010
Oxychlordane	8	0.009	0.003-0.016	ND-0.032
Cis-chlordane	4	0.010	0-0.019	ND-0.032
Cis-nonachlor	1	0.002	0-0.007	ND-0.022
Toxaphene	1	0.002	0-0.006	ND-0.019
Endrin	1	<0.001	0-0.003	ND-0.009
PCB's	10	0.539	0.25-0.90	0.13-1.7
Kodiak Island				
N = 11; 1975; 8.4				
DDE	11	0.073	0.031-0.12	0.029-0.27
DDD	4	0.004	0-0.009	ND-0.015
DDT	1	<0.001	0-0.001	ND-0.004
Dieldrin	6	0.006	0.002-0.010	ND-0.015
Heptachlor epoxide	3	0.003	0-0.008	ND-0.016
Oxychlordane	9	0.044	0-0.10	ND-0.34
Cis-chlordane	6	0.004	0.001-0.008	ND-0.012
Cis-nonachlor	2	0.002	0-0.006	ND-0.019
HCB	11	0.023	0.015-0.032	0.011-0.048
Toxaphene	6	0.005	0.001-0.008	ND-0.012
PCB's	11	0.610	0.47-0.77	0.31-1.0
Aleutian Islands				
Buldir Island				
N = 3; 1975; 10.5				
DDE	3	0.089	0.025-0.16	0.073-0.12
DDD	3	0.011	0-0.033	0.006-0.021
DDT	3	0.012	0.002-0.022	0.008-0.016
Heptachlor epoxide	3	0.009	0.009-0.009	0.009-0.009
Mirex	3	0.009	0-0.018	0.006-0.013
Oxychlordane	3	0.035	0.024-0.046	0.032-0.04
Cis-chlordane	3	0.008	0-0.019	0.005-0.013
Cis-nonachlor	1	0.005	0-0.016	ND-0.015
HCB	3	0.026	0.013-0.038	0.021-0.031
PCB's	3	0.931	0.092-2.4	0.61-1.5

Appendix III. Continued

		Residues in ppm (wet weight)		
Region; site: N, year, and PCB DDE; and chemical	No. with residues	Mean	95% CI	Range
Bristol Bay				
Round Island				
N = 6; 1973; 13.4				
DDE	6	0.014	0.011-0.018	0.009-0.17
Dieldrin	6	0.005	0.004-0.006	0.004-0.007
Mirex	2	0.002	0-0.005	ND-0.006
Oxychlordane	4	0.004	0-0.007	ND-0.006
Cis-nonachlor	2	0.002	0-0.004	ND-0.005
HCB	5	0.018	0.003-0.03	ND-0.039
PCB's	6	0.187	0.12-0.26	0.13-0.30
Shaiak Island				
N = 3; 1973; 6.8				
DDE	3	0.035	0.007-0.064	0.026-0.048
Dieldrin	3	0.007	0.001-0.013	0.005-0.010
Heptachlor epoxide	2	0.004	0-0.011	ND-0.006
Oxychlordane	3	0.025	0-0.099	0.009-0.059
Cis-nonachlor	3	0.006	0.002-0.010	0.004-0.007
HCB	3	0.026	0-0.090	0.006-0.054
PCB's	3	0.239	0.076-0.43	0.17-0.31
Pribilof Islands				
St. Paul Island				
N = 10; 1975; 14.3				
DDE	10	0.033	0.022-0.044	0.014-0.066
Dieldrin	1	<0.001	0-0.002	ND-0.006
Heptachlor epoxide	5	0.003	0-0.006	ND-0.013
Oxychlordane	10	0.034	0.029-0.039	0.023-0.043
HCB	10	0.043	0.033-0.054	0.015-0.060
Toxaphene	10	0.025	0.021-0.030	0.019-0.036
PCB's	10	0.472	0.35-0.60	0.23-0.68
Seward Peninsula				
Bluff Seabird Cliffs				
N = 9; 1976; 11.1				
DDE	9	0.033	0.022-0.045	0.020-0.068
DDD	2	0.001	0-0.003	ND-0.007
Dieldrin	2	<0.001	0-0.002	ND-0.004
Heptachlor epoxide	4	0.002	0-0.004	ND-0.006
Mirex	2	0.001	0-0.003	ND-0.005
Oxychlordane	9	0.010	0.007-0.014	0.004-0.017
Cis-chlordane	4	0.002	0-0.004	ND-0.006
Cis-nonachlor	3	0.001	0-0.002	ND-0.005
HCB	9	0.031	0.025-0.037	0.016-0.044
PCB's	9	0.365	0.31-0.42	0.26-0.48
M. Arctic tern (N = 3; lipid content = 6.23 ± 1.08%)				
Gulf of Alaska				
Kodiak Island				
N = 3; 1976; 7.5				
DDE	3	0.199	0.091-0.32	0.16-0.25
Oxychlordane	3	0.006	0.004-0.008	0.005-0.007
PCB's	3	1.49	1.1-2.0	1.3-1.6

Appendix III. Continued

Region; site; N, year, and PCB/DDE; and chemical	No. with residues	Residues in ppm (wet weight)		
		Mean	95% CI	Range
N. Aleutian tern (N = 6; lipid content = 7.08 ± 0.56%)				
Aleutian Islands				
Attu Island				
N = 6; 1975; 0.8				
DDE	6	0.432	0.16-0.76	0.16-0.98
DDD	4	0.008	0-0.017	ND-0.019
Dieldrin	6	0.011	0.006-0.015	0.004-0.016
Heptachlor epoxide	4	0.004	0-0.008	ND-0.007
Oxychlordane	6	0.009	0.007-0.010	0.007-0.012
Cis-chlordane	3	0.005	0-0.011	ND-0.012
HCB	6	0.005	0.004-0.005	0.004-0.006
Toxaphene	5	0.029	0.013-0.045	ND-0.044
PCB's	6	0.324	0.22-0.44	0.18-0.46
O. Common murre (N = 65; lipid content = 9.31 ± 0.17%)				
Gulf of Alaska				
Middleton Island				
N = 10; 1976; 1.6				
DDE	10	0.649	0.38-0.97	0.31-2.0
DDD	9	0.033	0.018-0.048	ND-0.077
DDT	6	0.017	0.003-0.031	ND-0.053
Dieldrin	5	0.026	0-0.067	ND-0.20
Heptachlor epoxide	6	0.011	0.002-0.021	ND-0.037
Oxychlordane	10	0.042	0.033-0.051	0.021-0.059
Cis-chlordane	5	0.012	0.002-0.022	ND-0.038
Cis-nonachlor	5	0.008	0-0.017	ND-0.029
Toxaphene	4	0.023	0-0.051	ND-0.12
PCB's	10	1.05	0.43-1.9	0.17-4.7
Ugaiushak Island				
N = 7; 1974; 0.8				
DDE	7	0.202	0.060-0.36	0.086-0.56
DDD	1	0.002	0-0.008	ND-0.016
DDT	1	0.002	0-0.007	ND-0.015
Heptachlor epoxide	2	0.005	0-0.013	ND-0.023
Oxychlordane	4	0.008	0-0.015	ND-0.018
Cis-chlordane	1	0.002	0-0.006	ND-0.012
Cis-nonachlor	5	0.014	0-0.029	ND-0.044
HCB	7	0.027	0.016-0.038	0.007-0.042
Toxaphene	2	0.014	0-0.037	ND-0.064
PCB's	7	0.168	0-0.39	0.021-0.76
Aleutian Islands				
Bogoslof Island				
N = 7; 1973; 1.1				
DDE	7	0.119	0.11-0.13	0.10-0.13
DDD	1	0.001	0-0.004	ND-0.008
Dieldrin	6	0.034	0-0.073	ND-0.12
Heptachlor epoxide	4	0.004	0-0.008	ND-0.009
Oxychlordane	6	0.005	0.002-0.008	ND-0.009
Cis-chlordane	1	<0.001	0-0.003	ND-0.005
Cis-nonachlor	4	0.008	0-0.016	ND-0.020
HCB	6	0.066	0.034-0.098	ND-0.096
PCB's	7	0.126	0.092-0.16	0.080-0.18

Appendix III. Continued

Region: site: N, year, and PCB DDE: and chemical	No. with residues	Residues in ppm (wet weight) Mean	95% CI	Range
Buldir Island				
N = 1; 1974; 0.9				
DDE	1	0.230	–	–
Heptachlor epoxide	1	0.010	–	–
HCB	1	0.039	–	–
PCB's	1	0.210	–	–
Bristol Bay				
Round Island				
N = 4; 1973; 1.4				
DDE	4	0.111	0.061-0.16	0.064-0.13
Dieldrin	4	0.023	0.008-0.039	0.013-0.036
Heptachlor epoxide	4	0.008	0.005-0.011	0.005-0.009
Oxychlordane	4	0.010	0.007-0.013	0.008-0.012
Cis-nonachlor	4	0.013	0.008-0.018	0.009-0.015
HCB	4	0.098	0.032-0.17	0.036-0.12
PCB's	4	0.151	0.063-0.25	0.070-0.20
Sharak Island				
N = 5; 1973; 1.0				
DDE	5	0.153	0.034-0.29	0.073-0.34
Dieldrin	4	0.012	0-0.023	ND-0.023
Heptachlor epoxide	1	0.001	0-0.005	ND-0.006
Oxychlordane	2	0.002	0-0.007	ND-0.008
Cis-nonachlor	2	0.002	0-0.007	ND-0.008
HCB	5	0.100	0.037-0.17	0.024-0.17
PCB's	5	0.147	0.090-0.21	0.089-0.21
Pribilof Islands				
St. George Island				
N = 11; 1975; 1.0				
DDE	11	0.273	0.14-0.43	0.084-0.79
DDD	10	0.035	0.022-0.047	ND-0.068
DDT	10	0.013	0.007-0.019	ND-0.023
Dieldrin	7	0.009	0.002-0.016	ND-0.025
Heptachlor epoxide	11	0.012	0.009-0.015	0.005-0.019
Oxychlordane	11	0.018	0.012-0.024	0.004-0.032
HCB	11	0.079	0.059-0.098	0.048-0.16
Toxaphene	9	0.037	0.003-0.072	ND-0.19
PCB's	11	0.270	0.22-0.32	0.12-0.35
St. Paul Island				
N = 10; 1975; 1.5				
DDE	10	0.135	0.098-0.17	0.069-0.26
DDD	1	<0.001	0-0.002	ND-0.006
Dieldrin	6	0.005	0.001-0.008	ND-0.015
Heptachlor epoxide	9	0.011	0.005-0.016	ND-0.024
Oxychlordane	10	0.026	0.020-0.033	0.012-0.041
Cis-chlordane	1	<0.001	0-0.002	ND-0.006
Cis-nonachlor	2	0.002	0-0.004	ND-0.013
HCB	10	0.080	0.062-0.098	0.044-0.11
Toxaphene	8	0.019	0.008-0.029	ND-0.044
PCB's	10	0.205	0.16-0.25	0.11-0.31
Seward Peninsula				
Bluff Seabird Cliffs				
N = 10; 1976; 1.3				
DDE	10	0.141	0.11-0.18	0.068-0.23
DDD	9	0.010	0.002-0.017	ND-0.037

Appendix III. Continued

Region; site; N, year, and PCB DDE; and chemical	No. with residues	Residues in ppm (wet weight)		
		Mean	95% CI	Range
Dieldrin	1	<0.001	0-0.002	ND-0.005
Heptachlor epoxide	4	0.004	0-0.007	ND-0.016
Oxychlordane	10	0.023	0.012-0.033	0.006-0.047
Cis-chlordane	4	0.003	0-0.005	ND-0.009
Cis-nonachlor	2	0.001	0-0.003	ND-0.007
HCB	10	0.111	0.085-0.14	0.070-0.180
PCB's	10	0.182	0.14-0.23	0.11-0.28
P. Thick-billed murre (N = 24; lipid content = 9.08 ± 0.22%)				
Gulf of Alaska				
Ugaiushak Island				
N = 1, 1974; 5, 1976; 1.8				
DDE	6	0.147	0.11-0.18	0.094-0.20
Dieldrin	2	0.010	0-0.031	ND-0.051
Heptachlor epoxide	3	0.007	0-0.019	ND-0.029
Oxychlordane	5	0.019	0.003-0.035	ND-0.042
Cis-chlordane	1	0.003	0-0.012	ND-0.020
HCB	5	0.060	0.022-0.098	ND-0.094
PCB's	6	0.259	0.055-0.50	0.080-0.74
Aleutian Islands				
Buldir Island				
N = 8; 1974; 0.6				
DDE	8	0.145	0.088-0.21	0.066-0.26
Oxychlordane	1	0.001	0-0.002	ND-0.006
HCB	8	0.062	0-0.14	0.025-0.32
PCB's	8	0.090	0.036-0.15	0.029-0.20
Seward Peninsula				
King Island				
N = 10; 1976; 1.8				
DDE	10	0.166	0.13-0.21	0.053-0.23
DDD	7	0.009	0.002-0.016	ND-0.029
Dieldrin	4	0.004	0-0.008	ND-0.017
Heptachlor epoxide	7	0.006	0.002-0.010	ND-0.015
Mirex	1	<0.001	0-0.002	ND-0.006
Oxychlordane	10	0.021	0.015-0.026	0.009-0.035
Cis-chlordane	4	0.004	0-0.007	ND-0.014
Cis-nonachlor	2	0.001	0-0.004	ND-0.008
HCB	10	0.098	0.065-0.13	0.006-0.16
Toxaphene	2	0.003	0-0.007	ND-0.015
PCB's	10	0.307	0.24-0.38	0.14-0.50
Q. Pigeon guillemot (N = 4; lipid content = 7.68 ± 0.30%)				
Gulf of Alaska				
Ugaiushak Island				
N = 4; 1974; 1.0				
DDE	4	0.071	0.038-0.10	0.046-0.094
Dieldrin	1	0.002	0-0.007	ND-0.006
Oxychlordane	2	0.005	0.005-0.014	ND-0.012
Cis-chlordane	1	0.001	0-0.004	ND-0.004
Cis-nonachlor	3	0.005	0-0.012	ND-0.010
HCB	4	0.021	0.014-0.029	0.016-0.027
Toxaphene	4	0.015	0-0.034	0.005-0.029
PCB's	4	0.069	0.026-0.11	0.052-0.11

Appendix III. Continued

		Residues in ppm (wet weight)		
Region; site; N, year, and PCB DDE; and chemical	No. with residues	Mean	95% CI	Range
R. Ancient murrelet (N = 5; lipid content = 14.0 ± 1.1%)				
Aleutian Islands				
Buldir Island				
N = 5; 1974; 0.5				
DDE	5	1.61	0.91-2.6	0.75-2.4
DDD	3	0.005	0-0.012	ND-0.014
Heptachlor epoxide	3	0.004	0-0.008	ND-0.007
Oxychlordane	1	0.005	0-0.017	ND-0.023
Cis-chlordane	3	0.006	0-0.014	ND-0.014
Cis-nonachlor	5	0.023	0.016-0.029	0.015-0.028
HCB	3	0.002	0-0.005	ND-0.004
Toxaphene	5	0.030	0.022-0.038	0.024-0.040
PCB's	5	0.829	0.28-1.6	0.45-1.9
S. Horned puffin (N = 5; lipid content = 9.16 ± 0.61%)				
Gulf of Alaska				
Barren Islands				
N = 2; 1976; 1.2				
DDE	2	0.617	0-2.5	0.52-0.72
DDD	1	0.014	0-0.22	ND-0.029
DDT	1	0.006	0-0.093	ND-0.013
Dieldrin	2	0.052	0-0.72	0.012-0.093
Heptachlor epoxide	2	0.014	0-0.094	0.008-0.02
Mirex	1	0.004	0-0.050	ND-0.007
Oxychlordane	2	0.021	0.003-0.041	0.020-0.023
Cis-chlordane	2	0.036	0-0.17	0.026-0.046
Cis-nonachlor	1	0.006	0-0.085	ND-0.012
HCB	2	0.022	0-0.14	0.014-0.031
PCB's	2	0.730	0.61-0.86	0.72-0.74
Ugaiushak Island				
N = 2; 1974; 17.1				
DDE	2	0.017	0-0.063	0.014-0.021
DDD	1	0.003	0-0.045	ND-0.006
DDT	1	0.006	0-0.085	ND-0.012
Dieldrin	1	0.011	0-0.16	ND-0.022
Heptachlor epoxide	1	0.002	0-0.027	ND-0.004
Oxychlordane	2	0.009	0-0.025	0.008-0.010
Cis-chlordane	2	0.013	0-0.026	0.012-0.014
Cis-nonachlor	2	0.012	0-0.068	0.007-0.016
HCB	2	0.012	0-0.091	0.006-0.018
Toxaphene	2	0.050	0-0.30	0.033-0.068
PCB's	2	0.290	0.29-0.29	0.29-0.29
Aleutian Islands				
Buldir Island				
N = 1; 1974; 37.8				
DDE	1	0.009		—
DDD	1	0.005		
Dieldrin	1	0.005		
Oxychlordane	1	0.013		
Cis-chlordane	1	0.012		—
Toxaphene	1	0.020		
PCB's	1	0.340		—

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Appendix III. Continued

Region; site; N, year, and PCB/DDE; and chemical	No. with residues	Residues in ppm (wet weight) Mean	95% CI	Range
T. Tufted puffin (N = 71; lipid content = 8.05 ± 0.20%)				
Gulf of Alaska				
Hinchinbrook Island				
N = 10; 1976; 1.5				
DDE	10	0.408	0.34-0.50	0.27-0.54
DDD	10	0.033	0.024-0.041	0.021-0.054
DDT	10	0.025	0.013-0.037	0.009-0.068
Dieldrin	10	0.020	0.013-0.026	0.012-0.041
Heptachlor epoxide	9	0.011	0.008-0.014	ND-0.016
Mirex	10	0.014	0.003-0.025	0.004-0.057
Oxychlordane	10	0.017	0.012-0.022	0.005-0.028
Cis-chlordane	9	0.023	0.014-0.032	ND-0.045
Cis-nonachlor	8	0.014	0.007-0.021	ND-0.031
HCB	10	0.036	0.027-0.044	0.021-0.058
PCB's	10	0.625	0.53-0.72	0.46-0.85
Barren Islands				
N = 8; 1976; 1.9				
DDE	8	0.297	0.21-0.39	0.074-0.39
DDD	7	0.024	0.011-0.036	ND-0.043
DDT	4	0.011	0-0.024	ND-0.043
Dieldrin	8	0.026	0.015-0.037	0.012-0.047
Heptachlor epoxide	5	0.006	0.001-0.011	ND-0.017
Mirex	4	0.003	0-0.005	ND-0.007
Oxychlordane	8	0.019	0.007-0.030	0.006-0.043
Cis-chlordane	8	0.030	0.020-0.040	0.014-0.046
Cis-nonachlor	7	0.009	0.005-0.013	ND-0.015
HCB	7	0.033	0.018-0.048	ND-0.049
PCB's	8	0.574	0.40-0.77	0.14-0.86
Kodiak Island				
N = 9, 1975: 1, 1976: 1.6				
DDE	10	0.339	0.26-0.42	0.15-0.57
DDD	5	0.008	0-0.015	ND-0.031
DDT	3	0.002	0-0.004	ND-0.009
Dieldrin	9	0.016	0.006-0.025	ND-0.044
Heptachlor epoxide	9	0.012	0.007-0.016	ND-0.025
Mirex	2	0.001	0-0.003	ND-0.008
Oxychlordane	10	0.016	0.011-0.020	0.009-0.032
Cis-chlordane	9	0.012	0.004-0.020	ND-0.040
Cis-nonachlor	4	0.003	0-0.006	ND-0.012
HCB	10	0.024	0.019-0.029	0.017-0.038
Toxaphene	9	0.065	0.026-0.11	ND-0.20
PCB's	10	0.533	0.33-0.76	0.026-1.1
Ugaiushak Island				
N = 3, 1974: 19, 1976: 2.6				
DDE	22	0.205	0.18-0.23	0.14-0.36
DDD	18	0.016	0.010-0.021	ND-0.049
DDT	4	0.002	0-0.004	ND-0.016
Dieldrin	15	0.008	0.003-0.012	ND-0.048
Heptachlor epoxide 1974	0			
1976	14	0.005	0.003-0.006	ND-0.009
Mirex	8	0.007	0-0.013	ND-0.057
Oxychlordane	20	0.009	0.007-0.011	ND-0.016
Cis-chlordane	21	0.013	0.010-0.015	ND-0.028
Cis-nonachlor 1974	0			
1976	13	0.007	0.004-0.010	ND-0.020

Appendix III. Continued

Region; site; N, year, and PCB/DDE; and chemical	No. with residues	Residues in ppm (wet weight)		
		Mean	95% CI	Range
HCB	21	0.029	0.023-0.035	ND-0.065
Toxaphene	14	0.015	0.008-0.022	ND-0.060
PCB's	22	0.531	0.39-0.68	0.10-1.9
Semidi Islands				
N = 7; 1976; 1.6				
DDE	7	0.162	0.070-0.28	0.060-0.31
DDD	7	0.023	0.012-0.035	0.013-0.049
DDT	3	0.008	0-0.018	ND-0.025
Dieldrin	1	0.004	0-0.015	ND-0.030
Heptachlor epoxide	4	0.007	0-0.014	ND-0.021
Mirex	2	0.002	0-0.006	ND-0.010
Oxychlordane	5	0.009	0-0.018	ND-0.026
Cis-chlordane	3	0.014	0-0.037	ND-0.069
Cis-nonachlor	1	0.004	0-0.012	ND-0.025
HCB	7	0.032	0.023-0.041	0.017-0.046
Toxaphene	1	0.003	0-0.009	ND-0.018
PCB's	7	0.263	0.079-0.48	0.034-0.56
Shumagin Islands				
N = 6; 1976; 1.4				
DDE	6	0.368	0.17-0.60	0.12-0.65
DDD	6	0.024	0.013-0.036	0.006-0.037
DDT	2	0.014	0-0.047	ND-0.079
Dieldrin	1	0.005	0-0.020	ND-0.033
Heptachlor epoxide	6	0.009	0.004-0.014	0.003-0.016
Mirex	2	0.002	0-0.006	ND-0.009
Oxychlordane	5	0.019	0-0.050	ND-0.079
Cis-chlordane	6	0.018	0.012-0.025	0.012-0.030
Cis-nonachlor	2	0.003	0-0.007	ND-0.009
HCB	5	0.037	0.015-0.059	ND-0.058
Toxaphene	2	0.018	0-0.053	ND-0.082
PCB's	6	0.524	0.38-0.69	0.38-0.78
Aleutian Islands				
Buldir Island				
N = 2; 1975; 2.9				
DDE	2	0.135	0-0.34	0.12-0.15
Dieldrin	2	0.004	0-0.007	0.004-0.004
Heptachlor epoxide	2	0.005	0-0.011	0.005-0.006
Oxychlordane	2	0.009	0.005-0.012	0.008-0.009
HCB	2	0.014	0-0.047	0.012-0.017
Toxaphene	2	0.031	0-0.14	0.023-0.039
PCB's	2	0.395	0.33-0.46	0.39-0.40
Bristol Bay				
Shaiak Island				
N = 6; 1973; 1.6				
DDE	6	0.266	0.12-0.44	0.040-0.49
DDD	4	0.005	0-0.010	ND-0.013
DDT	2	0.002	0-0.005	ND-0.007
Dieldrin	5	0.020	0.006-0.034	ND-0.036
Heptachlor epoxide	4	0.004	0-0.008	ND-0.008
Mirex	5	0.006	0.003-0.010	ND-0.010
Oxychlordane	5	0.012	0.002-0.022	ND-0.028
Cis-chlordane	5	0.008	0.003-0.012	ND-0.011
Cis-nonachlor	4	0.006	0-0.013	ND-0.016
HCB	6	0.064	0.016-0.12	0.008-0.12
PCB's	6	0.423	0.17-0.73	0.060-0.82

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237. Waterfowl Status Report, 1978, compiled and edited by Albert N. Novara, Sharon L. Rhoades, Betty I. Hodges, and K. Duane Norman. 1981. 96 pp.
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